

ANALYSIS OF  
POLAR CAP ABSORPTION EVENTS  
I. EFFECT OF SOLAR AND SOLAR INDUCED  
CONDITIONS PRIOR TO THE PCA EVENTS

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ERRATA

- Table 1. PCA No. 28, Range of Start Times should be 16/0600 - 16/1200
- Table 2. BO, Basler & Owren, date should be 1964
- Table 3. PCA No. 31, Remove (5000) from the 2800 Mc/s column
- PCA No. 53, Radio Emissions, move 4100 from the 2800 Mc/s column to the 3750 Mc/s column

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## 1.0 SUMMARY AND RECOMMENDATIONS

### 1.1 Summary

This study has been based on an analysis of solar and solar and solar induced terrestrial phenomena during the period from a few days before to a few days after the occurrence of solar flares that are known to have produced proton streams that were detected in the vicinity of the earth as polar cap absorption events.

Most of the analysis is limited to 59 PCA events that can, with reasonable certainty, be associated with solar flares, although some attention will be given to an additional 47 small events in an effort to, where possible, increase the statistical significance of the associated phenomena.

In many respects the analysis carried out in this study is similar to statistical evaluations that have been made by a number of investigators who were looking for correlations between specific solar phenomena. However, the basic objective of this study has been quite different. We are searching for those solar phenomena, or conditions, or combinations that can be used to predict with an acceptable degree of confidence whether or not a dangerous radiation conditions will exist outside the earth's atmosphere or magnetic field from an observed condition on the sun. In addition, we must be able to evaluate the magnitude of the danger, and the amount of time available for protective action.

The characteristics of solar flares and the associated solar region, which are the source of the high energy particles that cause polar cap absorption events, have been evaluated in terms of those phenomena that are generally associated with, or are, indications of active solar regions.

These phenomena are treated individually and in combinations to assess the probability that a given condition or region might be the source of a proton stream.

Plage regions, sunspot groups, flares, loop prominences, short wave radio fadeouts, solar radio emissions at discrete frequencies, and spectral emissions of Type II and Type IV that are reliably associated with PCA events, have been studied.

Solar induced disturbances in the earth's magnetic field as indicated by the planetary three hours index,  $K_p$ , and derived daily index,  $A_p$ , for the four or five days preceding the PCA flare have been used in a search for a correlation between the geomagnetic conditions and the proton stream travel time and the intensity of the event.

In addition to the analysis of solar regions, flares, and flare induced phenomena associated with the PCA events, we have, for the purpose of comparison, analyzed a limited number of large and magnetically complex sunspot groups; large, bright and flare productive plage regions, all flares of importance 3+, and selected flares of importance 3.

It is possible at this time to eliminate some of the parameters or phenomena from primary consideration and recommend others for additional analysis:

Sunspot - If a proton event is observed, there is a high probability that the flare occurred in a large magnetically complex sunspot group; however, the probability that a large magnetically complex sunspot group will be the source of a proton producing flare is very small.

Proton producing flares are more likely to occur in sunspot groups that have remained constant in area  $\pm 10\%$ , or were increasing in area during a period of several days.

Plage Regions - Large, bright, and flare productive regions do not appear to be necessary conditions for the production of a PCA-flare.

Nearly 40% of the proton flares occurred in plage regions with average maximum areas less than 6000 millionths. Approximately 50% of the proton events occurred from plage regions during their second rotation. All but one of the PCA events occurred in plage regions in the second or later rotation. There is a very low probability that a new plage region will be the source of a proton flare.

Flares - There is a high probability that an importance 3+ flare will be followed by an important PCA event, if the flare is accompanied by a major short wave radio fadeout and a radio burst at a frequency between 2800 and 3750 Mc/s.

Loop Prominence - If a flare on the solar disk has an associated loop prominence, there are good indications that a proton event will follow.

Magnetic Conditions - The flare proton event delay time or event size does not appear to be influenced by the variation of the three hour  $K_p$  index or the derived daily  $A_p$  during the four or five days preceding the flare.

#### 1.2 Recommendations

Many of correlations and associations examined during this study were limited to the association of the chosen phenomena to PCA events, the extension of the analysis to non-PCA flares and solar regions that did not produce PCA events should be carried out.

Plage Regions - Plage characteristics during the four or five days prior to PCA-flares and non-PCA flares of importance 2+ and 3 should be classified. Plage turbulence prior to or during major flares, and in particular PCA flares, should be investigated by a careful study of flare patrol films.

Flares - Major flares not associated with PCA events should be analyzed in terms of the chosen parameters for possible distinguishing characteristics of PCA and non-PCA flares.

Radio Emissions - Sunspot groups associated with PCA flares should be investigated for radio emissions from flares preceding the PCA-flare. If the PCA-flare regions are radio noisy, the evaluation should be extended to spot groups with non-PCA flares of importance 3. A few cases of importance 3 flares not followed by PCA events have been investigated. This analysis should be extended to give a better statistical sample. In particular those cases where the flare was reported by at least one observatory with importance 3+, and was reduced to importance 3 in the McMath-Hulbert working list (Table 11).

Loop Prominence Systems - The association of loop prominences on the solar disk with PCA flares shows a good correlation, especially for the years 1960 through 1963 where prominences were found for 12 of the 16 disk flares and for four of the five limb flares. Conversely, there were only two disk loop prominences reported (Bruzek) that were not associated with PCA flares from the basic list, and one of these occurred at the time of a very small PCA (Number G22, Table 8).

On the basis of the outstanding success of PCA flare loop prominence association, a thorough search should be made for additional loop prominences at the time of the other PCA-flare during 1960 through 1963.

## 2.0 GENERAL STATISTICAL SUMMARY

### 2.1 Selected PCA Events

The 106 Polar Cap absorptions (PCA) or possible PCA's were chosen from a large number of original sources (Table 3) and catalogues of PCA events compiled by Bailey (1964), Basler and Owren (1964), Malitson (1963), Warwick and Haurwitz (1962) and the 5 volumes of the Solar Activity Catalogue, Jonah, Dodson-Prince, and Hedeman (1965). These PCA events have been classified into three groups:

(a) PCA events detected by two or more techniques that can be associated with a solar flare with reasonable certainty. There are 59 events in this group (Table 1, 3, 4, 5 and 6).

(b) Small PCA events and events for which a flare association is questionable or not possible. There are 24 events in this group (Table 7).

(c) Small PCA events during 1960 reported by Gregory only (24 events, Table 8).

While some of the events listed in Tables 7 and 8 will be analyzed in some detail the major effort of this study has been devoted to the 59 events listed in Table 1.

### 2.2 PCA-Flare Central Meridian Distance

The distribution of the 59 flares are shown in Table 1A in terms of flare importance and flare central meridian distance.

Flare Importance	E90 to E60	≤E60 to E30	≤E30 to CM	CM to ≤W30	W30 to ≤W60	≥W60	Total
1	0	0	0	0	0	1	1
2	2	2	3	2	1	3	13
2+	0	0	3	2	1	1	7
3	0	4	4	7	5	5	25
3+	1	2	3	2	5	0	13
Total	3	8	13	13	12	10	59

TABLE 1A

PCA Flares-Central Meridian Distance Distribution

This shows a distinct performance for the western two thirds of the visible hemisphere (81%). Slightly less than 50% of all flares occurred between East 30 and West 30. The heliographic distribution by flare importance is shown on Figure 1.

### 2.3 PCA-Flare Delay Time

Table 1B and Figure 2 show the PCA-flare delay time as a function of heliographic position and flare importance.

Disk Position	PCA DELAY TIME HOURS						Total
	≤1	>1 to ≤3	>3 to ≤6	>6 to ≤9	>9 to ≤12	>12	
E90 to E60	0	1	3	0	1	0	5
<E60 to E30	1	2	4	1	1	0	9
<E30 to CM	1	6	2	1	0	1	11
CM to <W30	4	4	3	1	0	1	13
W30 to <W60	5	4	2	1	0	0	12
≥W60	4	1	4	0	0	0	9
Total	15	18	18	4	2	2	59

TABLE 1B

### PCA-Flare Delay Times with Solar Disk Distribution

Table 1B shows that approximately 86% of the PCA events followed the flare by six hours or less. The flare associated with a given PCA was chosen as the flare of highest importance that preceded the flare by less than twelve hours. If there were two or more flares of importance equal to or greater than 2+ preceding the PCA, the final decision was based on an

analysis of the radio emissions in both the centimeter and meter wave lengths, and in some cases the previous activity of the sunspot groups and the importance of the short wave radio fadeout. Finally the association was checked against associations given in the scientific literature, and other things being equal the flare with the shortest delay time was chosen. If there were no major flares (importance  $\geq 2+$ ) reported during the 12 hour period, all flares of importance  $\leq 2$  were examined in terms of their position, associated radio emissions, short wave fadeouts and the previous activity of the sunspot groups. In general this procedure led to a more or less unambiguous flare choice.

#### 2.4 Prompt Flare Induced Phenomena

An examination of the associated data given in Tables 1 and 3 shows that every PCA flare was accompanied by a SWF, and all but three by a centimeter burst at one or more frequencies in the range from 2800 to 3750 Mc/s. All but three of the PCA flares were followed by a sudden commencement geomagnetic storm (SSC), or the SSC occurred within an acceptable time of two PCA flares (PCA numbers 12, 13; 43, 44; 50, 51; 52, 53; 54, 55). All but three of the PCA flares of importance 2+ or greater (importance based on the McMath-Hulbert working list) were followed by a Forbush decrease.

All but five of the shortwave radio fadeouts were of importance equal to or greater than 2, lasting for 30 minutes or more (PCA's 5, 14, 18, 22, and 24). In fact, 45 of the SWF's that accompanied a PCA flare lasted for more than 60 minutes.

Thirty-four of the centimeter bursts in the range 2800 to 3750 Mc/s had peak intensities greater than  $1000 \times 10^{-22}$ .  $W(m^2 c/s)^{-1}$

These statistical relations are summarized in Tables 3A

Flare Imp.	No. Flares	SWF	All*	IV	10cm	SSC	Fd
1	1	1	1	1	1	1	1
2	13	13	3	8	11	11	5
2+	7	7	6	6	7	7	7
3	25	25	20	24	24	24	23
3+	13	13	13	13	13	13	13
Total	59	59	43	52	56	56	49

\*All of the Solar and Terrestrial Effects: SWF, Spectral Emission, Type IV, Radio Emissions at Centimeter Wavelengths (at 2800, or 2980, or 3000, and/or 3750), SSC, and Forbush decrease (Fd)

TABLE 3A

Summary of Selected Phenomena Associated with the PCA Flares

Type II (slow drift bursts) are listed in Table 3, but were not included in Summary Table 3A, because of the lack of spectral observations at the time of a large percentage of PCA flares. The Type IV events include those observed either at Sydney DAPTO and/or Fort Davis and probable Type IV emissions on the basis of selected single frequency outbursts.

Flare Imp.	No. Flux Observations	<100	100 to 500	>500 to 1000	>1000 to 10000	>10000	Total
1	0	0	0	1	0	0	1
2	2	0	5	2	4	0	13
2+	0	1	2	1	2	1	7
3	1	1	3	3	15	2	25
3+	0	0	1	2	10	0	13
Total	3	2	11	9	31	3	59

TABLE 3B

The Distribution of Centimeter Flux From  
PCA Flares as a Function of Flare Importance



From Table 3 we see that 73% of the PCA flares produced peak flux at 2800 or 3750 Mc/s greater than  $500 \times 10^{-22} W(m^2 c/s)^{-1}$ . The distribution of flux intensity as a function of flare importance is shown in Table 3B. 92% of the importance 3+, and 80% of the importance 3 PCA flares produced peak flux greater than  $500 \times 10^{-22} W(m^2 c/s)^{-1}$ .

### 3.0 SUNSPOT GROUPS AND PCA EVENTS

#### 3.1 Large Spot Groups

While we find that 53 of the important PCA events were associated with flares that occurred in large sun spot groups (22 large, 31 large and magnetically complex) these PCA sun spot groups represented only 34 (or 7%) of the 471 large spot groups that were reported during the years 1954 through 1963 (Table 4A).

Year	Large (Max. Area ≥ 500 millionths Number of Total with PCA PCAs Spots			Large and $\delta$ or $\beta\gamma$ Number of Total with PCA PCAs Spots			Small Spots with PCAs Number
	with PCA	PCAs	Spots	with PCA	PCAs	Spots	Number
1954	0	0	1	0	0	0	0
1955	0	0	17	0	0	2	0
1956	0	0	81	3	3	9	1
1957	8	9	89	3	5	20	2
1958	8	11	80	0	0	19	0
1959	1	1	69	3	5	15	0
1960	0	0	19	5	11	14	2
1961	1	1	11	2	6	5	1
1962	0	0	8	0	0	4	0
1963	0	0	6	1	2	2	0
Totals	17	22	381	17	31	90	6

TABLE 4A

Sunspots with Maximum Areas ≥ 500 Millionths of the Solar Hemisphere and  
PCA Flare Distribution

34 of the PCA flares occurred in 20 different sun spot groups that during disk passage had maximum areas greater than 1000 millionths. (Table 4B) This represents only about 12 percent of the 153 sun spot groups in this category, as shown by years in Table 4B. 52 of these large spots had mean areas greater than 1000 millionths during the years 1954 through 1959. (Data are not available subsequent to 1959). While there appears to be a strong PCA-flares association with large sun spot groups, the probability that a

Year	Max. Area $\geq 1000$	Mean Area $\geq 1000$	Max. Area $\geq 1000$	
			With PCA	Total PCA
1954	0	0	0	0
1955	1	1	0	0
1956	29	8	1	1
1957	32	13	5	7
1958	38	13	4	9
1959	29	17	4	3
1960	15	-	3	7
1961	5	-	2	5
1962	3	-	0	0
1963	1	-	1	2
Total	153	52	20	34

TABLE 4B

Sunspot Groups with Maximum Area, and Mean Area  $\geq 1000$  Millionths

large sun spot group will, at some time during disk passage, be the source of a PCA flare is extremely small. Similarly there does not appear to be any real correlation between the morphology of sun spot groups, either large or small with the occurrence of a PCA flare. This is shown on Figure 5. where we have, among other parameters, plotted the daily area of all sun spot groups that had a maximum area  $\geq 1000$  millionths, during 1958. We have shown all flares of importance 3 associated with those sun spot group and the PCA flares.

We have also shown the daily areas of all sun spot groups with maximum areas  $< 1000$  millionth that were the source of an importance 3 flare or a PCA flare. The sun spot area data for the five days prior to the 32 PCA-flares through 1958 do not show any significant trend. We find:

- 2 - at the east limb
- 1 - formed on the disk the day before the flare
- 1 - intermittent
- 2 - small and variable
- 1 - large and variable
- 4 - decreasing
- 8 - increasing
- 13 - stable  $\pm 10\%$

Corrected daily sun spot area data are not available for 1959 and subsequent years.

### 3.2 Magnetic and Zurich Classification

A similar situation exists in the case of both sun spot magnetic, and the Zurich classifications, even though there is a strong PCA flare association with  $\delta$  or  $\beta\delta$  spot groups, and E, F, G, and H Zurich classes. This is shown on Table 4 where the PCA-flare day classifications are also shown.

The Zurich and magnetic classification of the PCA-flare sun spot groups on flare day are shown in Table 4C.

	E	F	G	H	J	A	C	D	Total
$\delta$	7	2	0	6	0	0	0	0	15
$\beta\delta$	14	6	2	0	0	0	0	0	22
$\beta$	8	1	1	1	0	0	1	3	15
$\alpha$	0	0	1	0	3	0	1	0	5
?	0	0	0	0	1	1	0	0	2
Total	29	9	4	7	4	1	2	3	59

TABLE 4C

#### The Zurich and Magnetic Classification of Sunspots on PCA Flare Days

It should be pointed out that in those cases where the flare occurred at either the east or west limb, the Zurich and magnetic classification was extrapolated on the basis of the following or preceding days values.

30 of the PCA flares were definitely associated with  $\delta$  or  $\beta\delta$  sunspot groups with an E, F, G, or H Zurich classification. Seven others may have belonged in this group based on extrapolation as mentioned above.

### 3.3 PCA Events Associated With Small Sunspot Groups

Six or 10% of the basic PCA events have been associated with flares from small sunspot groups (max. area  $< 500$  millionths). These are shown in table 4D.

PCA Serial No.	Date	Abs. db	Delay Time	Flare Imp	CMD	Integrated Flux
2	3-10-56	3.5	3 <sup>h</sup> 45 <sup>m</sup>	2	E88	--
11	8-09-57	3.1	4 <sup>h</sup> 50 <sup>m</sup>	2	E76	--
20	9-26-57	2.0	1 <sup>h</sup> 53 <sup>m</sup>	3	E15	--
43	4-28-60	3.5	1 <sup>h</sup> 00 <sup>m</sup>	3	E34	$5 \times 10^6$
46	5-06-60	16.0	1 <sup>h</sup> 56 <sup>m</sup>	3+	E07	$4 \times 10^6$
57	9-28-61	3.3	0 <sup>h</sup> 43 <sup>m</sup>	3	E29	$6 \times 10^6$

TABLE 4D

#### PCA Events From Small Sunspot Groups and Related Data

Except for the fact that the reported absorption for five of these PCA events was small, none of them show phenomena characteristics substantially different from those PCA events associated with large spot groups.

### 3.4 Heliographic Longitude Distribution of Proton Flare Sunspot Groups

The heliographic longitude of the sunspot group associated with the basic PCA flares is shown on Figure 3 divided into northern and southern hemisphere. When two or more flares occur in a single spot group, these multiple flare spots are considered as a single event and are shown without dividing lines. That is, Figure 3 shows 39 independent events, 26 or 67% of these events occur in the solar hemisphere between  $320^\circ$  and  $140^\circ$ .

It should be noted that 7 of the 17 PCA events that occurred between longitudes  $140^\circ$  and  $320^\circ$  produced integrated proton fluxes (protons/cm<sup>2</sup>, energy  $> 30$  Mev) equal to or greater than  $1.5 \times 10^6$  as shown below (see Table 6 also).

Event Number	1	11	26	30	31	32	38
Integrated Flux	$1.0 \times 10^9$	$1.5 \times 10^6$	$2.5 \times 10^8$	$7.0 \times 10^7$	$1.1 \times 10^8$	$6.0 \times 10^6$	$1.8 \times 10^6$

The intensity of the flux for the remaining 10 has not been determined but the intensity of the absorption was greater than 3 db for 6 of the 10 events.

This clearly indicates that while there is only about a 33% probability that a PCA event will occur in the hemisphere between longitudes  $140^\circ$  and  $320^\circ$ , 19% of those events for which an integrated flux  $> 10^6$  has been determined, were produced by flares from that hemisphere.

Figure 4 shows the longitude distribution of the 106 proton events from Tables 1, 7, and 8, where we have shown them as 75 independent events, with 64% in the apparently favored hemisphere. This is in surprisingly good agreement with the percentage from the Figure 3 distribution since the PCA flare choice and consequently the sunspot group, for several of the events in Tables 7 and 8 may be questionable. These results are in reasonable agreement with those derived by Warwick (1965) where she found that 33 or 73% of her 45 independent proton events were in this same hemisphere.

#### 4.0 PLAGE REGIONS

##### 4.1 Plage Area and Brightness

A preliminary investigation (Table 5) shows that the probability that a large (area greater than 10,000 millionths of the area of the solar hemisphere) or bright (average intensity  $> 3$ ) region will be the source of a PCA-flare is very small. Forty-three of the 59 PCA flares occurred in plage regions with average maximum areas less than 10,000; in fact 23 of the PCA flares were associated with plage regions with average maximum area equal to 6,000 or less.

##### 4.2 Flare Productivity

Flare productivity prior to the PCA flare has some significance. There are only nine cases where the number of flares from the PCA flare region was less than ten and in four of these cases the PCA-flare occurred near the east limb. Only one western quadrant PCA-flare region did not produce 10 or more flares prior to the PCA flare. Ten multiple PCA-flare regions accounted for 29 of the PCA flares. These multiple PCA-flare regions are shown on Tables 4 and 5.

## 5.0 FLARE IMPORTANCE

### 5.1 Major Flares and PCA Events

The distribution of PCA flares by importance is shown on Table 3A. Forty-five of the flares have importance  $\geq 2+$ . The number of PCA flares of importance 2+, 3, and 3+ by years is shown in Table 1C together with the total number of flares reported in each of these categories based on the solar activity catalogue and the McMath-Hulbert working lists.

	<u>All Reported Flares Importance</u>			<u>Flares with PCA's Importance</u>		
	2+	3	3+	2+	3	3+
1954	0	0	0	0	0	0
1955	9	4	0	0	0	0
1956	38	21	1	0	2	0
1957	39	24	7	2	8	3
1958	58	17	3	2	3	3
1959	33	24	6	0	2	4
1960	22	15	4	3	5	2
1961	4	9	1	0	4	1
1962	3	2	0	0	0	0
1963	1	2	0	0	1	0
TOTAL	207	118	22	7	25	13
Table 7 (Small PCA)				2	2	1
Table 8 (Very small PCA)				2	5	2
TOTAL	207	118	22	11	32	16

TABLE 1C

### ALL FLARES AND PCA FLARE WITH IMPORTANCE $\geq 2+$

The number of PCA flares given in Table 1C by years is based on the major PCA events of Table 1. If we include the small PCA's from Table 7 and the Gregory PCA events from Table 8 for statistical purposes, we find that only 5.3% of the importances 2+ flares, 18.6% of the importance 3 flares, and 73% of the importance 3+ flares were followed by PCA events.



The importance 3+ flares are summarized in Tables 10A, 10B, and 10C and the six importance 3+ flares that were not followed by a PCA event are discussed in the appendix where it is concluded on the basis of associated phenomena that a PCA event would have been expected from two and not expected from the other four.

In the case of the very small PCA events, an analysis indicates that only one of the four had the potential of a major PCA event.

## 5.2 Flares with Importance 3+ by at Least One Observatory

A total of 53 flares were reported in the IAU Quarterly Bulletin and included in the Solar Activity Catalogue with an importance of 3+ by at least one solar observatory. Thirty of these flares were reduced to importance 3 or less in the McMath-Hulbert working lists as shown in Table 11A.

From Importance 3+ to:	Importance				Total
	3	2+	2	1	
1956	1	0	0	0	1
1957	5	0	0	0	5
1958	3	1	2	1	7
1959	5	0	1	0	6
1960	4	1	1	0	6
1961	3	2	0	0	5
TOTAL	21	4	4	1	30

TABLE 11A

### IAU IMPORTANCE 3+ FLARES REDUCED TO IMPORTANCE $\leq 3$ IN THE MCMATH-HULBERT WORKING LISTS

The 21 importance 3+ flares that were reduced to importance 3 in the McMath-Hulbert working list are listed in Table 11 together with the prompt flare associated data.

Nine of these flares (Numbers 1, 3, 4, 10, 14, 16, 18, 19, and 21) were followed by PCA events (Numbers 3, 15, 33, 38, 47, 50, 53 55--Table 1). The remaining 22 flares with importance 3+ in the IAU Bulletin, the Solar Activity Catalogue, and the McMath-Hulbert Flaring List are listed in Tables 10A, 10B, and 10C. Flares that were followed by very small PCA events, or by no PCA are evaluated in detail.

### 5.3 Importance 3+ Flares Followed by Large PCA Events

Twelve of the final list of importance 3+ flares (Table 10A) were followed within five hours by PCA's with total integrated flux greater than  $10^6$  protons/cm<sup>2</sup> with energies  $> 30$  Mev. These 12 flares occurred in ten different plage regions with average maximum area: 4 ranged from 4,000 to 15,000 millionths of the solar hemisphere, and average brightness of 3 (two cases), 3.5 (seven cases), and 4 (one case). Six of the ten associated sunspot groups had an average magnetic classification of  $\gamma$ , or  $\beta\gamma$ , two were bipolar ( $\beta$ ) and two were unipolar ( $\alpha$ ).

All of these flares caused short wave radio fadeouts of importance 3 (5 cases) or 3+ (7 cases) lasting for 30 minutes or more (all but two lasted for more than two hours). All of these flares were accompanied by major radio bursts lasting for 30 minutes or more, at one or more of the frequencies 2800, 2980, 3000, or 3750 Mc/s and spectral emissions of Type IV.

### 5.4 Importance 3+ Flares Followed by Very Small PCA Events

Four of the importance 3+ flares were followed by very small PCA's (Table 10B). Three caused short wave radio fadeouts of importance 3 (two cases) and 3+ (one case) lasting for more than 30 minutes. Only one was

accompanied by a major radio burst in the centimeter wave length (at 2980 Mc/s). From an analysis of the prompt flare associated phenomena (see Appendix 1, Section 1), only one of these flares (Number 3, Table 10B) satisfies the condition for an important PCA event. An integrated proton flux of  $4 \times 10^5/\text{cm}^2$  for energies  $> 30$  Mev has been calculated for this event.

#### 5.5 Importance 3+ Flares Not Followed by PCA Events

Table 10C lists six importance 3+ flares that were not followed by PCA events. Three were reported by the Sydney Observatory only and do not satisfy any of the conditions for PCA events. These flares and associated data are discussed in detail in Appendix 1, Section 2. Two of these flares (Numbers 5 and 6, Table 10C) meets the conditions for an important PCA event and must at the present time be considered as a false alarm.

Importance 3+ Flares	22
Important PCA's Expected	15
Important PCA's Reported	12
False Alarm Rate	1.3/1

#### 5.6 PCA Intensity and Flare Importance

The distribution of PCA intensity with flare importance is shown in Table 1D. However, it must be pointed out that the maximum absorption is more qualitative than quantitative, since the total energy or total flux during a PCA event will depend on the rate of rise, recovery and the duration of the event. The integrated proton flux for protons with energies greater than 30 Mev is known for only 36 of the 59 events.

Flare Imp.	Weak	$< 3$	$3 \leq \text{to } 5$	$> 5 \text{ to } 10$	$\geq 10$	Total
1	1	0	0	0	0	1
2	2	0	5	5	1	13
2+	0	2	3	1	1	7
3	2	6	11	1	5	25
3+	1	0	1	2	9	13
TOTAL	6	8	20	9	16	59

TABLE 1D

PCA INTENSITY AND FLARE IMPORTANCE

As a first approximation, from a comparison of the absorption in db with the events for which the integrated flux is known we find only four events with an integrated flux  $> 10^6$  protons/cm<sup>2</sup> from events following flares of importance  $< 2+$ , one is a flare at the west limb, the other at east 76.

A more complete evaluation of PCA events associated with flares of importance  $\leq 2+$ , is desirable.

## 6.0 OTHER PROMPT PHENOMENA

### 6.1 Solar Radio Bursts at Centimeters Wavelength

The correlation analysis of solar radio bursts at 28,000, and 3750 Mc/s, with proton events was made by the Radiation and Fields Branch, MSC. That analysis was based on the original records from Ottawa (2800 Mc/s) and Nagoya (3750 Mc/s). More than 200 bursts were found with an integrated intensity greater than  $10^{-18}$  joules  $(\text{m}^2 \text{ c/s})^{-1}$ . In this study we have limited the investigation to the radio frequency bursts that occurred at the time of the PCA flares listed in Tables 1, 7 and 8. Peak fluxes or the smoothed flux (when the peak flux was not available) were used, at the frequencies 2800, 2980, 3000, or 3750 Mc/s. If a flux was not reported, an attempt was made to determine if observations were being made at the time of the flare. An examination of Tables 3 and 3A shows that a flux was reported at 2800, and 3750 Mc/s for 56 of the 59 PCA events listed in Table 1. The number of radio frequency bursts in several ranges of intensity are shown in Tables 3C, where flare importance has been used as a parameter. This shows, as was expected, a strong correlation between the major bursts (peak flux  $> 500 \times 10^{-22} (\text{m}^2 \text{ c/s})^{-1}$ ) and major flares (importance  $\geq 2+$ ).

A correlation of the integrated RF burst energy for all 56 cases shown in Tables 3 and 3B with the PCA intensity and, where available, the event integrated proton flux supplemented with data for 3000, and 2980 Mc/s should be carried out.

These data when combined with the other correlation studies may help to reduce the false alarm rate. In fact, since the SPAN telescopes will cover the frequencies 1420, 2695, and 4995 Mc/s, an analysis of the additional frequencies might be productive.

Observatory Code	Frequencies	Normal Observing Time, Hr. UT
HHI	1500	06-15
Syd	1420	21-07
Nag	2000	23-07
Tok	3000	00-06

Forty-three of the 59 PCA-flare events shown on Tables 1 and 3 occurred during the observing periods of one or more of these observatories. The six hours of the universal day (1500-2100) not patrolled by those observatories are covered by the normal patrol period at Ottawa.

In Table 3C we have listed the 12 PCA events where the peak or smoothed flux at 2800 Mc/s was less than 200, and those where the PCA-flare occurred outside the normal Ottawa observing time at 2800 Mc/s. In this table we have included all observing frequencies between 1420 and 3750 Mc/s.

PCA No.	Date	Flare Beg.	Frequencies Mc/s						
			2800	3750	1420	1500	2000	2980	3000
4	11-30-56	1430	(175)	*	*	**	*	*	**
5	1-20-57	1100	(184)	*	*	**	**	184	**
6	4-03-57	0825	*	*	*	(147)	*	22	**
14	8-29-57	1031	*	*	*	(151)	*	x	x
20	9-26-57	1907	(67)	*	*	*	*	*	*
22	2-10-58	9/2108	(>70)	*	{207}	*	*	*	*
					{857}				
25	6-06-58	0436	*	(360)	343	*	420	*	**
33	2-13-59	12/2301	*	(440)	**	*	(335)	*	*
39	3-29-60	0640	*	8250	x	*	$4.9 \times 10^4$	**	**
44	4-29-60	0107	*	115	x	*	x	*	**
50	11-15-60	0207	*	11600	x	*	4950	*	**
58	9-20-63	2314	*	1400	**	*	1200	*	*

\* Outside observing time

\*\* Not observing

x No flux reported

Bracket indicates smoothed flux

TABLE 3C

PCA Events with Very Low Flux at 2800 Mc/s or When the Flare Occurred Outside the Normal Ottawa Observing Time

It should be noted that the normal observing times both beginning and ending vary by one or two hours with the season.

## 6.2 Spectral Emissions - Broad Band Continuum - Type IV

Type IV spectral emissions were observed by either the Harvard or Sydney radio observatories or a type IV emission was derived by a number of investigators from single frequency observations for 52 of the 59 PCA events listed in Tables 1 and 3. The seven cases where no type IV was reported in the literature are summarized in table 3D .

PCA No.	Date	Flare		Type IV	2800	3750	Integrated Proton Flux
		Beg.	Imp.				
2	3-10-65	0515	2	*	850	*	--
5	1-20-57	1100	3	*	(184)	*	$2 \times 10^8$
11	8-9-57	0617	2	**	246	(105)	$1.5 \times 10^6$
13	8-29-57	28/2010	2+	x	(760)	*	$1.2 \times 10^8$
14	8-29-57	1031	2	*	*	*	--
24	3-25-58	0557	2	xx	458	(106)	--
32	9-22-58	0738	2	*	336	(49)	$6 \times 10^6$

\* No observations

\*\* No observations, Sydney stopped at 0616 UT

x None reported, Harvard observing

xx None reported, Sydney observing

TABLE 3D

PCA Events With No Reported Type IV Emissions

The study confirms the high correlation between PCA events and spectral emissions type IV. However, the 52 type IV emissions observed and derived and associated with a PCA flare represents a small percentage of the total number observed or derived during the years 1954 through 1963, as shown in table 3E.

	Total		With PCA	
	Obs.	Derived	Obs.	Derived
1954	0	0	0	0
1955	0	0	0	0
1956	1	28	0	3
1957	22	50	12	1
1958	21	26	8	1
1959	24	24	5	1
1960	42	8	10	3
1961	19	2	4	2
1962	8	2	0	0
1963	2	1	1	1
Total	139	141	40	12

TABLE 3E

Spectral Type IV Emissions, and PCA Events



Only 19 percent of the observed and derived type IV emissions occurred at the time of flares that were followed by PCA events.

A more complete analysis of spectral emissions, type II and type IV with emissions at fixed frequency in the range 1420 through 3750 Mc/s, and flare importance, may show a better correlation with PCA events.

### 6.3 Short Wave Radio Fadeout (SWF)

An inspection of tables 1, 3 and 3A shows that every PCA-flare was accompanied by a SWF, all but four of the SWF's were of importance equal to or greater than 2, lasting for 30 minutes or more. In fact 45 of the PCA flare-SWF's lasted for more than 60 minutes.

The significance of this PCA-flare, SWF correlation should be investigated further as a possible input parameter for the solar proton warning criteria.

### 6.4 Loop Prominence Systems

One of the most promising phenomena, which at this time has not been thoroughly evaluated because of lack of data, is the occurrence of loop prominences on the solar disk in association with a flare. A preliminary search for loop prominences reported in the IGY report series, combined with data published by Bruzek indicates a high probability that a disk flare which is associated with a loop prominence will be followed by a PCA event, and conversely the probability that a disk PCA-flare will have an associated loop prominence appears to be high. In any case the association is such that a careful evaluation should be made. The appearance of loop prominences at either the East or West limb does not appear to be as promising and must be taken into consideration before reliable conclusions can be made.

Table 6 shows the estimated PCA event proton flux (Protons/cm<sup>2</sup>) for energies  $> 30$  Mev., and those events for which loop prominence systems were reported in the literature or the IGY Solar Activity Report Series.

Table 6A summarizes the number of importance 3 and 3+ flares that were followed by an importance PCA event (from tables 1 and 6) and the number of Loop Prominences at the time of these major flares (3 and 3+). Seven additional Loop Prominences originated from PCA-flares with importance  $< 3$  to give a total of at least 27 PCA events following flare with associated loop prominences.

	Flare Importance		LPS Bruzek or the IGY Rep. Series			
	3	3+	Yes		No	
			3	3+	3	3+
1956	2	0	0	0	2	0
1957	8	3	2	1	6	2
1958	3	3	1	1	2	2
1959	2	4	0	4	2	0
1960	5	2	4	2	1	0
1961	4	1	3	1	1	0
1962	0	0	0	0	0	0
1963	1	0	1	0	0	0
	25	13	11	9	14	4

TABLE 6A

Importance 3 and 3+ Flares  
And Associated Loop Prominence Systems

## 7.0 DELAYED TERRESTRIAL EFFECTS

### 7.1 Effect of Disturbances in the Earth's Magnetic Field

The condition of the interplanetary magnetic field at the time of the PCA flare, as implied by the three hour planetary index  $K_p$  fails to show any significant correlation with the PCA flare delay time or the intensity of the PCA. This is shown for selected but typical events in Figures 6, 7, and 8. In addition to showing the three hour  $K_p$  for the four days preceding the PCA flare, we have shown all flares from the PCA flare sunspot group, and where available, the normalized neutron monitor two hours counting rate, the daily sunspot area, known loop prominences, and sudden commencement of geomagnetic storms. The length of the line or size of the box indicates the importance or intensity of the event.

We have included cases of major flares (importance  $\geq 2+$ ) not followed by known PCA events (Figures 8A, 8B and 8C), but with an associated loop prominence; moderate to intense PCA events (Figures 6 and 7) and a sequence of three very small PCA events (Figure 8D).

An indication of the condition of the earth's magnetic field on PCA day for the PCA events from Table 1 is shown in the first two columns of the last section of Table 3 (PCA Day Values), where the  $\sum K_p$  and  $A_p$  are given.

This phase of the investigation will require a more complete analysis before firm conclusions can be made.

### 7.2 Geomagnetic Storms

Fifty-six of the basic PCA flares were followed by a sudden commencement geomagnetic storm or in a few cases where two or three PCA events occurred

within a 24 or 48 hour period, we have considered that the two or three PCA flares were followed by an SSC even though they were the same storm. The maximum storm  $K_p$  and time delay between the PCA and the SSC are shown in Table 3. Table 3F shows the distribution of the storm maximum  $K_p$  as a function of the PCA flare importance.

PCA Flare Imp.	No. Storm	Maximum Storm $K_p$				Total
		5+	5+ to 6-	6+ to 8-	8+	
1	0	0	0	1	0	1
2	2	0	1	7	3	13
2+	0	0	1	1	5	7
3	1	0	5	7	12	25
3+	0	0	1	6	6	13
TOTALS	3	0	8	22	26	59

TABLE 3 F

THE DISTRIBUTION OF SSC MAXIMUM  $K_p$   
WITH PCA FLARE IMPORTANCE

We see that a large percentage of the storms are moderate or severe more or less independent of the flare importance. The delay times from the start of the PCA to the start of the storm varies from four hours (PCA Number 4) to a maximum of 71 hours (PCA Number 49). In six cases the delay times were greater than 60 hours, and the PCA-SSC association might be questionable.

## APPENDIX 1

### IMPORTANCE 3+ FLARES FOLLOWED BY SMALL OR NO PCA EVENTS

The four importance 3+ flares that were followed by small PCA events (Table 10B) and six with no reported PCA events (Table 10C) are analyzed in considerable detail. It is concluded that an important PCA event would have been expected from the importance 3+ flare on September 18, 1957 this flare, followed by a small PCA, satisfied most of the conditions for a large PCA event. Similarly, the importance 3+ flare on June 18, 1959 was accompanied by the phenomena generally associated with the large PCA events.

#### 1. IMPORTANCE 3+ FLARES FOLLOWED BY SMALL PCA EVENTS

##### 1.1 Importance 3+ Flare, February 21, 1957

This flare at N20 W33 was followed in approximately two hours by a PCA (No. S3 Table 7) reported by several investigators on the basis of  $f_{\min}$  data. The reported onset times ranged from 1800 UT on the 21st (Jelly and Collins) to 1600 UT on the 22nd (Besprozvannaya). Basler and Owenlist this as two events, one on the 21st at 1800 UT, the other on the 22nd at 0500 UT.

The flare was reported in the IAU Bulletin from the Sacramento Peak Observatory in Region 46, but no importance was given. The flare is not included in Table 1, Volume 2 of the Solar Activity Catalogue. It is, however, reported as event 24 of Table VIII, Volume 2, with importance 3+ associated with sunspot 12140, plage 3856.

The plage, in its 4th rotation, was small (2800 millionths) moderately bright (average 2.5 intensity during disk passage) and was the source of only four flares (an importance 1 at 0530 UT the 21st, an importance 1+ at 0300 UT, the 22nd, and importance 1 on the 23rd).

This 3+ flare lasted for six hours with the reported maximum at 1930, nearly three and a half hours after the onset. No SWF is reported but a low intensity 10 cm burst (peak flux 19) starts at 1750 UT and lasts for four hours. Small bursts were reported at 200, and 167 Mc/s starting about 30 minutes after the flare beginning.

The association of this flare with a sunspot is questionable due to the intermittent appearance and disappearance of the three spots covered by the plage, (Mt. Wilson spots 12140 at N13, 12143 at N09, and 12150 at N09) and the location of the flare at N20 on the 21st two days after the disappearance of 12140. However, the association with an active region at heliographic longitude 10° is unquestionable. The spot (Greenwich No. 17876) attained a maximum area of 59 millionths on the 15th.

The other pair of spot groups (Mt. Wilson numbers 12143 and 12150) were located at N09. 12143, a three day spot, disappeared on the 16th while 12150 appeared on the 19th and was last seen on the 25th at W79. Greenwich spot 17875 was first seen on the 14th at E60, and was intermittent with a few small spots until the 16th (Mt. Wilson spot 12143). A new spot appeared on the 20th (Mt. Wilson spot 12150) with an area of 65 millionths. It developed rapidly and reached a maximum area of 729 millionths on the 23rd two days after the PCA flare. A major PCA event would not be expected.

#### 1.2 Importance 3+ Flare, September 18, 1957

This small PCA was reported by two independent investigators, but is not included in Bailey's Catalogue. The reported start times range from 2000 UT on the 18th (Besprozvannaya) to 0400 on the 19th (Khocholava).

The flare that was probably responsible occurred in a large (area 1998 millionths on flare day) magnetically complex (d $\beta\delta$  1) sunspot group

which was first seen on September 13 at E75. The group which formed from a few small spots developed rapidly into a large stream of normal type. The bright plage (number 4151) (intensity 3.5/4.0/3.0) had an average maximum area of 7500 millionths and was flare productive (83 flares during disk passage). In addition to the large spot group the plage contained two small groups that lasted for only three days (12637,  $d\beta_p d$ , September 21-23, and 12632,  $d\beta_p d$ , September 20-22).

The sunspot was the source of 32 flares of importance 1; 4 of importance 2; 1 importance 2+ and one importance 3, prior to the importance 3+ flare at 1658 on the 18th. The flare lasted for nearly 5 hours, caused a major short wave radio fadeout, (importance 3+ lasting for 150 minutes) small radio bursts at centimeter wave lengths, and an importance 3 spectral emission, type IV in the frequency range 580 - 100 Mc/s that lasted for more than 6 hours. There were major bursts of long duration at 167, 450, and 545 Mc/s. The flare was followed by a sudden commencement geomagnetic storm (max Kp = 7+) and a Forbush decrease of 6%.

This flare starting at 1658 UT on the 18th followed within slightly more than one hour of an importance 3 flare in the same plage and spot group which started at 1026 and ended at 1613. Both of these flares had resurgences (or double aspects) the earlier (importance 3) flare had maximum values at 1045, and 1325 with the two phases starting at 1026 and 1303 with major short wave radio fade outs at 1030 (importance 3 lasting 104 minutes) and 1245 (importance 3- lasting 95 minutes). The importance 3+ flare under discussion had maximum intensities at 1740 and 1840 with short wave fades at 1730 and 1823 both of importance 3+ and both lasting 150 minutes.

On the basis of the importance of the region, the flare associated phenomena and the central meridian position and the importance of the flares at 1026, 1303, 1658, and 1818. A solar proton event of major importance would have been expected.

### 1.3 Two Very Small PCA Events During 1960

Gregory reports 24 very small PCA events which he detected from an analysis of high sensitivity vertical-incidence back scatter sounding of the lower ionosphere at a frequency of 2.3 Mc/s at South 79° geomagnetic latitude, ionosond  $f_{\min}$  data from high latitude stations confirm these events.

The 24 small events, Table 8 were not reported by other investigators. Two of these very small events were associated with importance 3+ flares (numbers G20 and G38 Table 8). These are analyzed in detail to determine, if possible, why large PCA events were not detected and the possible effect on a solar warning false alarm occurrence.

#### 1.3.1 Importance 3+ Flare June 1, 1960

The flare at 0824 UT, N29 E46 on June 1, 1960 was observed by a record number of observatories (19 reported the flare) and ten gave it an importance of 3+. The flare lasted for five hours and seventeen minutes, and was accompanied by a short wave fade of importance 3 lasting for 75 minutes. There were great bursts at 2980 Mc/s, (lasting for 63 minutes with a peak flux greater than 3400) and 200 Mc/s (lasting for 75 minutes with a peak flux of 3100). Great bursts were also recorded at 9100, 1500, 600, 545, and 23 Mc/s. There was no sweep frequency spectral observation of the sun at the time of the flare, but because of the great bursts at single frequencies in both the centimeter and meter wave lengths, a type IV emission probable occurred throughout the complete frequency range of the



radio spectrum. A Forbush decrease of 4.5 percent was reported by Chalk River starting at approximately 2200 UT on June 3. A sudden commencement geomagnetic storm started at 0248 on June 4, with a maximum three-hour Kp of 6+. Gregory reports a small PCA starting approximately five and a half hours after the flare, lasting for about 6 days. Jelly and Collins report a PCA commencing at 2000 UT on the 3rd lasting about 3 days.

Increased proton counting rates were reported in Explorer VII data during the northern high latitude passes on June 1, and again on June 4 (Table 6).

Although there were 11 importance 1, and 1+ flares between 0823 on the 1st and 1900 UT on the third, it is not probable that any of these small flares was responsible for the Jelly and Collins PCA. It is probable that the Jelly and Collins PCA, and the increased proton counting rates observed by Explorer VII were all from a plasma cloud ejected from the sun by the flare of June 1.

The flare occurred in a high latitude  $\beta$  type spot (N29) at heliographic longitude  $343^\circ$ . This spot is a return of the large (1800 millionths) magnetically complex ( $\gamma$  type) spot 14825 which crossed the visible disk at mean longitude  $352^\circ$ , which was the source of an importance 3 flare on May 13, followed by a great short wave fade and a polar cap absorption (number 47, Tables 1, 3, 4, and 5). The great flare on June 1 and sunspot were in a large (area 7000 millionths) moderately bright (average intensity equal to 3) and flare productive (34 flares importance  $\geq 1$  during disk passage) plage 5680.

While this flare did produce a small PCA (too small to be detected by the forward scatter technique or by Riometers), the characteristics of

the flare and associated phenomena indicates that a high flux proton beam should have reached the vicinity of the earth within a few hours after the start of the flare. An integrated proton flux of  $4 \times 10^5$  protons/cm<sup>2</sup> for energies  $> 30$  Mev has been calculated for this event by Webber.

1.3.2 The Importance 3+ Flare, December 5, 1960

This very small PCA found by Gregory, and not detectable on Riometer records or by the forward scatter technique, started approximately eleven hours after the importance 3+ flare at 1825 UT, N26 E68, on December 5. The flare was accompanied by a major SWF (importance 3 lasting 100 minutes) Type II and Type IV spectral emissions, a moderate burst at 2800 Mc/s (peak intensity 330), a major burst at 200 Mc/s (peak intensity greater than 1000) and small bursts at 545 and 108 Mc/s.

The flare occurred in the magnetically complex spot group (1~~9~~1) 15151, region 1434-38 at N28 and heliographic longitude 8°. The plage 5959 was moderate in area, (6500 millionths) and brightness, (average intensity 3), and was the location of 13 flares during disk passage.

Because of the eastern location of this flare on the solar disk (E68) and the low peak intensity of the 2800 Mc/s flux ( $330 \times 10^{-22} \text{ w m}^{-2} (\text{S/C})^{-1}$ ), this flare would not be classified for proton warning, but the region would be watched carefully during disk passage for later indications of a proton flare event. The plage in its fourth rotation was the return of plage 5925 which contained the large (area 1775 millionths) sunspot group 15114, which was the location of four very small PCA's on November 10, 11, 14, and 19, reported by Gregory only (numbers G31, G32, G34, and G36, Table 8) and the three major PCA events with ground level effects on November 12, 15 and 21. (Numbers 49, 50, and 51, Tables 1, 3, 4, and 5.)

2.0 IMPORTANCE 3+ FLARES WITH NO REPORTED PCA EVENT

2.1 Importance 3+ Flare, November 7, 1956

The importance 3+ flare at 1109 UT, S17 E32 occurred in the bright new plage 3751. The sunspot group 11949 crossed the visible disk between the 3rd and 15th November with  $\beta_p$  average magnetic classification, and a whole spot area on flare day of 929 millionths of the solar hemisphere. In spite of the large area of the sunspot only six importance 1 flares were reported prior to the importance 3+ flare. The first flare was reported on the 5th at E57. The sunspot was located at mean heliographic longitude  $264^\circ$ , which as seen from figures 3 and 4 is located in the region where PCA's are relatively rare..

The region was relatively radio quiet and no emissions in the frequency range from 3750 to 2800 were reported at the time of the importance 3+ flare. The flare produced an importance 2 short wave radio fadeout which lasted for only 21 minutes. Six of the minor flares were accompanied by moderate radio bursts of short duration at centimeter and/or meter wave lengths. This flare was followed at 1313 by a loop prominence.

On the basis of the relatively minor SWF and lack of emissions in the centimeter wave lengths an importance PCA would not be expected. However, because of the associated loop prominence a state of alert should be considered.

2.2 Importance 3+ Flare, January 23, 1957

This importance 3+ flare at 2310, N17, W17, was reported by only one observatory (Sydney) in Region 19, sunspot 12089, plage 2823.

The flare occurred in the large, (16000) bright, (3.5, 3.5, 3) flare productive (37 flares) plage region in its third rotation. The plage covered

three sunspot groups. The sunspot in which the flare occurred (12089) had a maximum area of 1581 millionths, a mean area during disk passage of 778 millionths with an  $\alpha_p$  magnetic classification and Zurich type H, at mean longitude  $18^\circ$ . There were no radio emissions at centimeter wave lengths reported at the time of the flare and no SWF was reported. A major burst was reported by NBS at 167 Mc/s with peak flux greater than  $2100 \times 10^{-22} \text{ Wm}^{-2} (\text{c/s})^{-1}$ .

Six importance 1, 4 importance 2, and 1 importance 2+ flares were reported in this region prior to the 3+ flare, the first flare (importance 1) occurred at E50 on January 18. No PCA would be expected from this flare.

### 2.3 Importance 3+ Flare, January 31, 1957

This importance 3+ flare at 0358 UT was also reported by only one observatory (Sydney) in Region 30, sunspot 12114, plage 3830.

This plage (in its second rotation) was of moderate size (8500), moderately bright (3/3/3). The plage contained two one day spots, one spot that was born and died on the visible disk and the flare-spot which was first seen on January 27 (Zurich and Greenwich) at E54 and mean longitude  $257.4^\circ$ . This small (mean area 160 millionths) stream of spots achieved a maximum area of 504 millionths on the 29th, but covered only 183 millionths of the solar hemisphere at the time of the flare on the 31st. It continued to decrease in size to 64 millionths by February 3 and to 40 millionths at W72 when it was last seen on February 5.

Only 3 flares were reported in this region, one of importance 1, and one of importance 2 on February 1, and the 3+ flare under evaluation. This flare was accompanied by small radio bursts at 9400 Mc/s (41 smoothed flux) and at 3000 Mc/s (234 peak flux). A minor SWF (importance 1) lasting

for 84 minutes is associated with the flare. None of the characteristics or phenomena associated with this flare, except the reported importance, would indicate a PCA.

2.4 Importance 3+ Flare November 29, 1957

This flare at 0045 UT was followed by a Type II burst of short duration and a moderate burst (488 peak flux) at 9500 Mc/s. No associated SWF was reported. This flare occurred in a very small plage (4282) at very high latitude (N41) and near the east limb (E63). The plage contained no spots, this, the only known flare in the plage region, was reported by the Sydney observatory only. No PCA could be expected under these conditions, in fact, the reported flare importance would be questionable.

2.5 Importance 3+ Flare on April 5, 1959

This flare at 2316 UT, N16 W67, occurred in the bright (average intensity  $> 3$ ) flare productive (46 flares) plage, 5071, which is a fifth return region. This plage contained three spot groups that existed during the complete disk passage and two short lived groups. The flare occurred in the small (mean area 184 millionths) but magnetically complex ( $\beta\delta$ ) sunspot group 14020. An importance 3+ short wave fade lasting for 93 minutes started almost simultaneously with the start of the flare. There were no 2800 Mc/s observation at the time of the flare, and no Type II or Type IV dynamic emissions were reported. However, there were great bursts at 9500 Mc/s (2960 peak flux) 3750 Mc/s (smoothed flux 2300 lasting for 8 minutes) and at 2000 Mc/s (smoothed flux 580). No sudden commencement geomagnetic storm or Forbush decrease followed within three days after the flare, although a solar flare effect (magnetic crochet) was reported by 17 stations commencing at 2321 UT on the 5th. The four days prior to the flare were

very quiet geomagnetically with a maximum 3-hour Kp of 3+ and Ap's of 6, 7, 12 and 6, respectively.

The flare was preceded by 24 minor flares and one importance 2+ flare. The first flare was reported at E48 on March 28.

The sunspot group was at mean longitude 273°. On the basis of this flare and the associated phenomena, including the SWF and burst at 3750 Mc/s. A PCA might be expected unless one considers that the region lies in the apparent region between Heliographic Longitudes 140° and 320° where very few PCA's have been reported.

#### 2.6 Importance 3+ Flare in June 18, 1959

This flare at 1134 UT, N18 W67, occurred in a large, (area 9000 millionths), bright, (average intensity 3.5) and flare productive (96 flares during disk passage) plage 5204. The plage contained two spot groups that accompanied it across the east limb and a small one day spot. The flare occurred in the large (maximum area 1111 millionths, mean area 856 millionths) magnetically complex (  $\gamma$  type) sunspot group 14211 at heliographic longitude 330°. This spot was a Zurich type G on flare day and the source of 43 minor and 3 major flares prior to the 3+ flare on the 18th. The first flare (importance 2) occurred at the east limb on June 9 and was accompanied by a great shortwave fade of importance 3+ lasting for 180 minutes, two great bursts at 2800 Mc/s and a Type IV broad band continuum emission in the very low frequency range (50-25 Mc/s). This region was unusually active and radio noisy during disk passage.

The importance 3+ flare was accompanied by a SWF of importance 2+ that lasted for 52 minutes. Very large complex radio bursts were reported at centimeter wave length commencing simultaneously, the emission at 2800

Mc/s lasted for three hours with a smoothed flux of  $1225 \times 10^{-22} \text{ Wm}^{-2}$   $(\text{c/s})^{-1}$ . No emissions were reported at meter wave lengths. The small PCA, observed by Riometers and from  $f_{\min}$  data on June 13 (Number S17, Table 7) was associated with an importance 1 flare from this same region at E58, at a time of very quiet geomagnetic conditions, when except for a brief period (4th, 5th and 6th three-hour periods) on the 11th, the three hour Kp's remained less than 30 during the four days preceding the flare.

This is the one real failure among the importance 3+ flares since all of the flare-time related phenomena indicate a probable PCA of considerable magnitude. The sunspot longitude of  $330^\circ$  is in the apparent preferred hemisphere for PCA's.

It is interesting to note that during the next solar rotation the plage 5204 combined with 5218 to form the plage 5265, and sunspot 14211 returned as 14284 which was the source of the three high energy PCA flares on the 10th, 14th and 16th of July 1959 (Numbers 35, 36, and 37, Table 1).

### SOURCES OF DATA

Polar Cap Absorption Events. The original sources used to compile the list of polar cap absorption events given in Tables 1, 7, and 8 are given in Table 3.

Solar and Terrestrial Phenomena used in the study of the PCA events were taken from Solar Activity Catalogue Volumes 1 through 5, prepared by F. C. Jonah, Helen Dodson-Prince and E. Ruth Hedeman under NASA Contract NAS 9-2469.

Sources used for the preparation of the Solar Activity Catalogue are listed in each volume of the catalogue.

Daily Sunspot Areas for the years 1954 through 1958 were obtained from Royal Greenwich Observatory Bulletins Photo Heliographic Results: 1955, published 1958 (no number); 1956 (Bulletin Number 14); 1957 (Bulletin Number 26); 1958 (Bulletin Number 60).

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Many sources of data on special solar events published in the scientific literature, not listed in Table 3, were consulted during this study.

No attempt is made to give a complete list of scientific papers, reporting special solar events. Only those directly related to polar cap absorption events have been included in the Bibliography.



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**TABLE 1**  
**PCA'S WITH ASSOCIATED FLARES AND SOURCES**

No.	Date	PCA Reg.	Rise Time, hrs.	Duration hrs.	Abs. db.	Flare Onset Max.	Imp.	Position	At	Range Start Times	Original Sources	Others
<b>1956</b>												
1.	Feb. 23	0400	18	123	13.0	0334 --	3	M23 W80	0 <sup>h</sup> 23 <sup>m</sup>	23/0400-23/0600	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>JM</sub> , J <sub>P</sub> , S	M, Mo, WH
2.	Mar. 10	0900	38	160	3.5	0515 --	2	M16 E88	3 <sup>h</sup> 45 <sup>m</sup>	10/0900-11/1600	B <sub>1</sub> , Be, C <sub>JM</sub>	M
3.	Aug. 31	1430	14	69	4.9	1226 1246	3+(3)	M15 E15	2 <sup>h</sup> 04 <sup>m</sup>	31/1430-31/1800	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>JM</sub> , J <sub>P</sub> , S	M, Mo, WH
4.	Nov. 13	2000	27	63	5.4	1430 1501	2	M16 W10	5 <sup>h</sup> 30 <sup>m</sup>	13/1400-14/1600	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>JM</sub>	M, Mo, WH
<b>1957</b>												
5.	Jan. 20	1500	16	86	4.1	1100 1119	3	S30 W18	4 <sup>h</sup> 00 <sup>m</sup>	20/1500-21/1500	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>JM</sub> , DLP, S	BO, M, Mo, WH
6.	Apr. 3	1330	14	65	3.9	0825 0835	3	S14 W60	5 <sup>h</sup> 05 <sup>m</sup>	02/2300-04/1200	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>JM</sub> , J <sub>P</sub>	BO, M, Mc, WH
7.	June 19	2215				Weak 1609 1613	2+(2)	M20 E45	6 <sup>h</sup> 06 <sup>m</sup>	19/2215-19/2300	Be, J <sub>P</sub> , S	BO
8.	June 22	0500	44	115	5.0	0236 --	2	M23 E12	2 <sup>h</sup> 24 <sup>m</sup>	22/0500-22/1000	B <sub>1</sub> , B <sub>2</sub> , K, RL, S	BO, M, WH
9.	July 3	0900	12	52	9.2	0712 0745 0830 0840	3+ 3+	M14 W40 M10 W42	1 <sup>h</sup> 42 <sup>m</sup> 0 <sup>h</sup> 30 <sup>m</sup>	03/0815-03/1030	B <sub>1</sub> , B <sub>2</sub> , Be, Bo, DLP, H <sub>2</sub> , HNS, H, J <sub>P</sub> , K, OH, PS, RL, S	BO, K, Mo, WH
10.	July 24	2015		27	2.0	1712 1737 1801 1822	3	S24 W27	3 <sup>h</sup> 05 <sup>m</sup>	24/1000-24/2400	B <sub>2</sub> , Bo, H, H <sub>2</sub> , HNS, J <sub>P</sub> , K, OH, PS, RL, S	BO, M, Mo, WH
11.	Aug. 9	1600	10	50	3.1	0617 0629	2	S09 E76	9 <sup>h</sup> 43 <sup>m</sup>	09/1500-09/2400	B <sub>1</sub> , Be, H, J <sub>C</sub> , K, PS	BO, M
12.	Aug. 28	1300				Weak 0810 0955	3+(3)	S30 E35	4 <sup>h</sup> 50 <sup>m</sup>	28/0400-28/2300	A, Be, Bo, DLP, H, PS	BO, Mo
13.	Aug. 29	0000	7	27	3.2	28/2010 2024	3(2+)	S28 E30	3 <sup>h</sup> 50 <sup>m</sup>	29/0000-29/0500	A, B <sub>1</sub> , B <sub>2</sub> , H <sub>2</sub> , HNS, OH, PS, S	BO, M, Mo, WH
14.	Aug. 29	1300	12	58	8.2	1031 1052	3(2)	S25 E20	3 <sup>h</sup> 29 <sup>m</sup>	29/1300-29/1500	A, B <sub>1</sub> , B <sub>2</sub> , DLP, H <sub>2</sub> , HNS, K, OH, RL, S	BO, M, WH
15.	Aug. 31	1415	12	46	4.9	1257 1313	3+(3)	M25 W02	1 <sup>h</sup> 18 <sup>m</sup>	31/1415-31/1530	A, B <sub>1</sub> , B <sub>2</sub> , H, K, S	BO, M, Mo, WH
16.	Sept. 02	1700	9	46	7.2	1313	3(2+)	S34 W36	3 <sup>h</sup> 47 <sup>m</sup>	02/1500-02/2100	B <sub>1</sub> , B <sub>2</sub> , Bo, HNS, H, K, OH, RL, S	BO, M, Mo, WH
17.	Sept. 12	0200	13	57	0.5	11/0236 0300	3	M13 W02	23 <sup>h</sup> 24 <sup>m</sup>	12/0200-12/2315	B <sub>2</sub> , Be, Bo, DLP, H <sub>2</sub> , HNS, H, J <sub>P</sub> , K, Kh, OH, PS, RL, S	BO, M, Mo, WH
18.	Sept. 18	2000				18 1658 1740 1818 1840	3+	M23 E08	3 <sup>h</sup> 02 <sup>m</sup> 1 <sup>h</sup> 42 <sup>m</sup>	18/2000-19/0400	Be, DLP, H, Kh, PS	BO
19.	Sept. 21	1700	18	63	5.1	1330 1335	3	M10 W06	3 <sup>h</sup> 30 <sup>m</sup>	21/1200-21/2115	B, B <sub>2</sub> , C <sub>JM</sub> , H <sub>2</sub> , HNS, H, K, OH, PS, RL, S	BO, M, Mo, WH
20.	Sept. 26	2100		31	2.0	1907 1952	3	M22 E15	1 <sup>h</sup> 53 <sup>m</sup>	26/2100-26/2315	B <sub>1</sub> , Be, Bo, H <sub>2</sub> , HNS, H, K, Kh, OH, PS, RL, S	BO, M, WH
21.	Oct. 20	2100	22	64	7.8	1637 1642	3+	S26 W45	4 <sup>h</sup> 23 <sup>m</sup>	20/1700-21/1400	B <sub>1</sub> , Be, Bo, C <sub>JM</sub> , DLP, H <sub>2</sub> , HNS, H, J <sub>P</sub> , K, Kh, OH, PS, RL, S	BO, M, Mo, WH
<b>1958</b>												
22.	Feb. 10	0600	14	37	3.2	9/2108 2142	2+	S12 W14	8 <sup>h</sup> 52 <sup>m</sup>	10/0500-10/2400	B <sub>1</sub> , B <sub>2</sub> , Be, Bo, C <sub>JM</sub> , DLP, H <sub>2</sub> , HNS, K, Kh, OH, PS, RL, S	BO, M, Mo, WH
23.	Mar. 23	1500	34	53	3.2	0947 1005	3+	S14 E78	5 <sup>h</sup> 13 <sup>m</sup>	23/1500-23/1830	B <sub>1</sub> , B <sub>2</sub> , Bo	BO, M, Mo, WH
24.	Mar. 25	1530	13	122	10.0	0557	2	S15 E50	9 <sup>h</sup> 33 <sup>m</sup>	25/0100-25/1545	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>JM</sub> , DLP, H <sub>2</sub> , HNS, K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
25.	June 06	0600				Weak 0436 0448	3(2)	M16 W78	1 <sup>h</sup> 12 <sup>m</sup>	04/2300-06/1345	Be, Bo, DLP, H <sub>2</sub> , HNS, Kh, OH, PS, S	BO, M, WH
26.	July 07	0130	22	96	23.7	0020 0110	3+	M25 W08	0 <sup>h</sup> 20 <sup>m</sup>	07/0100-07/0600	B <sub>1</sub> , B <sub>2</sub> , Be, Bo, C <sub>JM</sub> , DLP, H <sub>2</sub> , HNS, J <sub>P</sub> , K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
27.	July 29	0400		30	1.5	0259 0304	3	S14 W44	1 <sup>h</sup> 01 <sup>m</sup>	29/0400-29/0500	B <sub>2</sub> , Be, Bo, DLP, H <sub>2</sub> , HNS, J <sub>P</sub> , K, Kh, OH, RL, S	BO, M, Mo, WH
28.	Aug. 16	0600	16 (2 db/hr)	71	215.0	0433 0440	3+	S14 W50	1 <sup>h</sup> 28 <sup>m</sup>	29/0600-16/1200	B <sub>1</sub> , B <sub>2</sub> , Be, Bo, C <sub>JM</sub> , DLP, H <sub>2</sub> , HNS, J <sub>P</sub> , K, Kh, L, OH, PS, RL, S, ETV	BO, M, Mo, WH
29.	Aug. 21	1400	0.2 db/hr	19	3.0	20/0042 0045	3(2+)	M16 E17	13 <sup>h</sup> 18 <sup>m</sup>	21/1400-21/1730	B <sub>1</sub> , Be, DLP, HNS, K, Kh, L, RL, S	BO, M, WH
30.	Aug. 22	1530	11	84	10.6	1417 1450	3	M18 W10	1 <sup>h</sup> 23 <sup>m</sup>	22/1500-22/1745	B <sub>1</sub> , B <sub>2</sub> , Bo, C <sub>JM</sub> , DLP, H <sub>2</sub> , HNS, K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
31.	Aug. 26	0100	1 db/hr	89	16.6	0005 0027	3	M20 W54	0 <sup>h</sup> 55 <sup>m</sup>	26/0100-26/0400	B <sub>1</sub> , B <sub>2</sub> , Bo, C <sub>JM</sub> , DLP, H <sub>2</sub> , HNS, J <sub>P</sub> , K, Kh, L, OH, PS, RL, S	BO, M, Mo, WH
32.	Sept. 22	1400	22	80	5.0	0738 0750	2+(2)	S19 W42	6 <sup>h</sup> 22 <sup>m</sup>	22/0530-22/1730	B <sub>1</sub> , B <sub>2</sub> , Be, Bo, H <sub>2</sub> , HNS, J <sub>P</sub> , K, Kh, OH, PS, RL, S	BO, M, Mo, WH
<b>1959</b>												
33.	Feb. 13	0800	12	74	2.6	12/2301 2325	3+(3)	M13 E48	8 <sup>h</sup> 59 <sup>m</sup>	13/0800-13/1400	B <sub>1</sub> , Be, J <sub>C</sub> , J <sub>P</sub>	BO
34.	May 10	2300	3 db/hr	170	22.0	2055 2140	3+	M19 E47	2 <sup>h</sup> 05 <sup>m</sup>	10/2300-11/0300	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>JM</sub> , DLP, HNS, J <sub>P</sub> , K, Kh, L, OH, RL, S, SL	BO, M, Mo, WH

PCA'S WITH ASSOCIATED FLARES AND SOURCES (cont.)

No.	Date	PCA Beg.	Rise Time, hrs.	Duration hrs.	Abs. db.	Flare Onset	Max.	Imp.	Position	t	Range Start Times	Original Sources	Others
35.	July 10	0400	0.9 db/hr	360	20.0	0206	0230	3+	E20 E60	1 <sup>h</sup> 54 <sup>m</sup>	9/2000-10/1000	B <sub>1</sub> , B <sub>2</sub> , Be, C <sub>1</sub> M, DLP, EHO, K, <u>Kh</u> , L, OH, RL, S, <u>SL</u>	BO, M, Mo, WH
36.	July 14	0445	27	72	23.7	0325	0349 0527	3+	E17 E04	1 <sup>h</sup> 20 <sup>m</sup>	14/0445-14/0800	B <sub>1</sub> , B <sub>2</sub> , C <sub>1</sub> M, DLP, EHO, <u>K</u> , <u>Kh</u> , L, OH, RL, S, <u>SL</u>	BO, M, Mo, WH
37.	July 16	2250	10	168	21.2	2114	2128	3+	E16 W30	1 <sup>h</sup> 30 <sup>m</sup>	16/2200-17/0600	B <sub>1</sub> , B <sub>2</sub> , C <sub>1</sub> M, <u>DE</u> , EHO, JP, <u>K</u> , <u>Kh</u> , <u>L</u> , OH, <u>RL</u> , S, <u>SL</u>	BO, Mo, WH
38.	Aug. 18	1100		60	3.0	1014	1030	3+(3)	E12 W33	0 <sup>h</sup> 40 <sup>m</sup>	18/1100-19/1000	B <sub>1</sub> , <u>Be</u> , DLP, JC, JP, K, S	BO
<u>1960</u>													
39.	Mar. 29	0800	50	73	2.6	0640	0710	3(2+)	E13 E30	1 <sup>h</sup> 20 <sup>m</sup>	29/0800-29/1100	B <sub>1</sub> , B <sub>2</sub> , G	BO, Mo
40.	Mar. 30	2000		>36	5.0	1455	1540	3+(2)	E12 E13	5 <sup>h</sup> 05 <sup>m</sup>	30/1100-31/0700	B <sub>2</sub> , DE, EHO, GM, JP, K, L, S, Sat.	BO, M, Mo, WH
41.	Apr. 01	1000	6	73	3.6	0843	0859	3	E12 W11	1 <sup>h</sup> 17 <sup>m</sup>	01/0930-01/1000	B <sub>1</sub> , B <sub>2</sub> , G, GM, K, L, S, Sat	BO, M, Mo, WH
42.	Apr. 05	0400	>16	55	3.1	0215	0245	3(2)	E12 W62	1 <sup>h</sup> 45 <sup>m</sup>	05/0400-05/1400	B <sub>1</sub> , B <sub>2</sub> , EHO, G, GM, K, L, S, Sat.	BO, M, Mo, WH
43.	Apr. 28	0230	12	30	3.5	0130	0137	3	S05 E34	1 <sup>h</sup> 0 <sup>m</sup>	28/0200-28/1000	B <sub>1</sub> , B <sub>2</sub> , EHO, G, GM, JP, K, L, S, Sat	BO, M, Mo, WH
44.	Apr. 29	0400	0.4 db/hr	114	14.0	0107	0210 0359 0554	3(2+)	E14 W21	2 <sup>h</sup> 53 <sup>m</sup>	29/0200-29/700	B <sub>1</sub> , B <sub>2</sub> , EHO, G, GK, JP, K, L, S, Sat	BO, M, Mo, WH
45.	May 04	1030	3.2 db/hr	8	3.4	1000	1016	3	E13 W90	0 <sup>h</sup> 30 <sup>m</sup>	04/1030-04/1200	B <sub>1</sub> , B <sub>2</sub> , EHO, G, JP, K, L, S, Sat	BO, M, Mo, WH
46.	May 06	1600	0.15-0.33 db/hr	103	16.0	1404	1448	3+	S09 E07	1 <sup>h</sup> 50 <sup>m</sup>	06/1400-06/1800	B <sub>1</sub> , B <sub>2</sub> , EHO, G, JP, K, L, S	BO, M, Mo, WH
47.	May 13	0620	0.7 db/hr	65	4.5	0519	0532	3+(3)	E29 W67	1 <sup>h</sup> 01 <sup>m</sup>	13/0620-13/0800	B <sub>1</sub> , B <sub>2</sub> , EHO, G, JP, <u>K</u> , <u>L</u> , S, Sat	BO, M, Mo, WH
48.	Sept. 03	0500	31	89	2.7	0037	0108	3(2+)	E18 E88	4 <sup>h</sup> 23 <sup>m</sup>	03/0500-03/2300	B <sub>1</sub> , B <sub>2</sub> , EHO, G, JC, K, S	BO, M, Mo, WH
49.	Nov. 12	1400	16	73	21.2	1315	1330	3+	E27 W04	0 <sup>h</sup> 45 <sup>m</sup>	12/1400-12/1600	B <sub>1</sub> , B <sub>2</sub> , G, JP, <u>K</u> , S, Sat	BO, M, Mo, WH
50.	Nov. 15	0430	15	79	20.0	0207	0221	3+(3)	E26 W35	2 <sup>h</sup> 23 <sup>m</sup>	15/043-15/1200	B <sub>1</sub> , B <sub>2</sub> , G, JP, K, S, Sat.	BO, M, Mo, WH
51.	Nov. 21	0200	15	51	3.0	20/1955 20/2114	2020 2135	3(1) 3(2)	E25 W90 E28 W90	6 <sup>h</sup> 05 <sup>m</sup> 4 <sup>h</sup> 46 <sup>m</sup>	21/0000-21/1300	B <sub>1</sub> , B <sub>2</sub> , G, JP, S	BO, M, Mo, WH
<u>1961</u>													
52.	July 11	2200	0.08 db/hr		1.3	1615	1659 1710	3	S07 E31	5 <sup>h</sup> 45 <sup>m</sup>	11/2200-11/2400	L, M, Sat	BO, M, Mo
53.	July 12	1900	0.8 db/hr	72	17.0	0950	1025	3+(3)	S07 E22	9 <sup>h</sup> 10 <sup>m</sup>	12/1300-12/2115	B <sub>1</sub> , JP, L <sub>2</sub> , Sat	BO, M, Mo, WH
54.	July 18	1130	8	55	10.0	0920	1005	3+	S07 W59	2 <sup>h</sup> 10 <sup>m</sup>	18/1130-18/1200	B <sub>1</sub> , JP, L <sub>2</sub> , Sat	BO, M, Mo, WH
55.	July 20	2200			Weak	{1553 1633 1828}	{1600 1653 1847}	3+(3)	S05 W90	{6 <sup>h</sup> 07 <sup>m</sup> 5 <sup>h</sup> 27 <sup>m</sup> 3 <sup>h</sup> 32 <sup>m</sup> }		L <sub>2</sub> , Sat	BO, M, Mo, WH
56.	Sept. 10	2000	18	79	2.9	1555	1610	1	E10 W90	4 <sup>h</sup> 05 <sup>m</sup>	10/2000-10/2300	B <sub>1</sub> , <u>BO</u> , Sat	M, Mo
57.	Sept. 28	2245	1.7 db/h pre-sec 3.3 db/h post-sec		3.3	2202	2223	3	E13 E29	0 <sup>h</sup> 43 <sup>m</sup>	10/2245-10/2335	B <sub>1</sub> , L, L <sub>2</sub> , Sat, <u>Bel</u>	BO, M, Mo, WH
<u>1963</u>													
58.	Sept. 20	2400	15	54	3.1	2314	2403	2	E10 W09	0 <sup>h</sup> 40 <sup>m</sup>		B <sub>1</sub> , <u>BO</u> ,	
59.	Sept. 26	0745	8	89	4.6	0638	0717	3	E13 W78	1 <sup>h</sup> 07 <sup>m</sup>	26/0730-26/0745	B <sub>1</sub> , <u>BO</u>	

TABLE 2  
SOURCES USED FOR POLAR CAP ABSORPTION DATA

A	Anderson	J. Geophys. Res.	<u>69</u>	1964	1743-1753
B <sub>1</sub>	Bailey	Planet. Space Sci.	<u>12</u>	1964	495-541
B <sub>2</sub>	Bailey	J. Phys. Soc. Japan	<u>17</u> A-1	1962	106-112
Be	Besprosvannaya	J. Phys. Soc. Japan	<u>17</u> A-1	1962	146-150
Bo	Bookin	J. Phys. Soc. Japan	<u>17</u> A-1	1962	150-151
BO	Basler & Owen	U. Alaska Geophys. Inst.	R-152	1962	189 pp.
CJM	Collins, Jelly & Matthews	Can. J. Phys.	<u>39</u>	1961	35-52
DM	Dodson & Hedeman	Ark. Geofysik	<u>3</u>	1962	469-470
DLP	Dvoryashin, Levitskii & Pankratov	Soviet Astron. A.J.	<u>5</u>	1961	311-325
EHO	Egeland, Hultqvist & Ortner	Ark. Geofysik	<u>3</u>	1962	481-488
FW	Freier & Webber	J. Geophys. Res.	<u>68</u>	1963	1605-1629
Go	Gosling	J. Geophys. Res.	<u>69</u>	1964	1233-1238
G	Gregory	J. Geophys. Res.	<u>68</u>	1963	3097-3107
GM	Greenstadt & Moreton	J. Geophys. Res.	<u>67</u>	1962	3299-3316
H	Hill	J. Phys. Soc. Japan	<u>17</u> A-1	1962	97-102
HG	Hakura & Goh	J. Radio Res. Lab. Japan	<u>5</u>	1959	635-650
HNS	Hakura, Nagai & Sano	Rep. Ionosph. Space Res. Japan	<u>15</u>	1961	14-30
JC	Jelly & Collins	Can. J. Phys.	<u>40</u>	1962	706-718
JP	Jenkins & Paghis	Can. J. Phys.	<u>41</u>	1963	1056-1075
K	Kahle	U. Alaska Geophys. Inst.	R-129	1962	76 pp.
Kh	Khocholava	Geomag. Aeronomy.	<u>2</u>	1962	90-96, 907-913
			<u>3</u>	1963	735-740
L <sub>1</sub>	Leinbach	U. Alaska Geophys. Inst.	R-127	1962	230 pp.
L <sub>2</sub>	Leinbach	U. Alaska Geophys. Inst.	R-126	1962	16 pp.
M	Malitson	NASA TR	R-169	1963	109-117
MW	Malitson & Webber	NASA TR	R-169	1963	1-17
Mo	Modisette	Manned Spacecraft Center Eng. Des. & Oper, Ed. Purser, et.al.		1964	97-104
OH	Obayashi & Hakura	J. Geophys. Res.	<u>65</u>	1960	3143-3148
PS	Piggott & Shapley	Antarctica Res. Geophys. Mon.	<u>7</u>	1962	111-120
RL	Reid & Leinbach	J. Geophys. Res.	<u>64</u>	1959	1801-1805
S	Sinno	J. Geomag. Geoelect.	<u>13</u>	1961	1-10
SL	Shapley & Lincoln	Ann. IDY	<u>16</u>	1962	289 pp.
WH	Warwick & Haurwitz	J. Geophys. Res.	<u>67</u>	1962	1317-1332



TABLE 3

SUMMARY FCA EVENTS AND FLARE RELATED PHENOMENA

	FCA	Flare Imp.	CSD	SWF	Radio Emissions				MUF, M3000				FCA	Σ	P	FCA Day Values				Area	Miles
					11	17	3750	2800	200	MUF	F2	Δf <sub>min</sub> /Δf <sub>max</sub>				Surf	Surf	Surf	Surf		
1.*	1986	2-23	3	W80	160/3+	0	(#)	(18000)	>4700	>20000	8+	1.5	0.5/47/6.5	13.0	13-	7	(R)	(J)	(J)	114	794
2.		3-10	2	W88	117/3-	-	-	-	850	x	6+	-	4.0/9/-	3.5	23-	20	A	-	-	-	-
3.*		8-31	3+(3)	W15	81/3	-	#	0	(2340)	22500	8+	6.5	2.0/35/1.5	4.9	23+	21	E	(J)	(J)	97	837
4.*	11-13	2	W10	120/2+	-	#	0	(175)	x		8+	2.5	5.5/4/0.5	5.4	21+	16	O	(J)	(J)	46	338
5.	1987	1-20	3	W18	13/1+	-	-	0	(184)	x	9-	17.0	4.0/22/5.5	4.1	8+	4	E	(R)	(R)	123	557
6.		4-03	3	W60	35/2+	-	#	0	0	>10	6-	1.9	5.0/43/-34	3.9	26+	20	E	(J)	(J)	110	682
7.		6-19	2+(2)	W45	44/3	#	#	0	(2325)	>260	-	-	6.0/-/-	Weak	23+	26	J	(J)	(J)	171	931
8.		6-22	2	W12	74/2	-	#	x	570	-	7+	-	2.5/68/-	5.0	23-	16	J	(J)	(J)	167	816
9.		7-03	3+	W40	61/2+	-	#	0	>600	3400	7+	4.0	1.5/39/0.5	9.2	30+	30	E	(J)	(J)	108	500
10.		7-24	3	W27	113/3	-	#	0	1275	385	-	-	3.0/-/-	2.0	20+	12	E	(J)	(J)	81	504
11.		8-09	2	W76	35/3-	-	-	(105)	246	110	-	-	9.5/-/-	3.1	23+	16	J	-	-	15	121
12.		8-28	3+(3)	W35	138/3	-	#	x	1192	100	7-	13.0	5.0/31/-	Weak	19+	10	E	(J)	(J)	95	774
13.		8-29	3(2+)	W30	18/2+	#	-	0	(760)	>450	-	-	4.0/20/2	3.2	22-	28	E	(J)	(J)	95	774
14.		8-29	3(2)	W20	16/1+	-	-	0	x	>230	7+	-	3.5/47/-	8.2	22-	28	E	(J)	(J)	171	807
15.		8-31	3+(3)	W02	184/3+	-	#	0	(3900)	>1200	9-	4.5	1.5/37/9	4.9	30+	36	E	(J)	(J)	227	1317
16.		9-03	3(2+)	W36	68/2-	-	(#)	0	429	(250)	9+	2.1	4.0/48/1	7.2	54+	135	O	(J)	(J)	101	686
17.		9-12	3	W02	110/3	#	#	(373)	1110	520	9-	6.1	23.5/49/3	0.5	15+	7	E	(J)	(J)	132	701
18.		9-18	3+	W08	150/3+	-	#	0	(275)	>293	7+	6.0	3.0/65/8	1	20-	12	F	(J)	(J)	376	1998
19.		9-21	3	W06	60/3-	-	#	0	(785)	>1250	9-	6.6	3.5/34/-	5.1	39+	74	E	(J)	(J)	136	491
20.		9-26	3	W15	100/2+	-	#	0	67	>384	9-	8	2.0/53/2	2.0	16+	8	C	(J)	(J)	49	232
21.		10-20	3+	W45	156/3+	#	#	0	(4000)	>120	7-	8.2	4.5/30/1	7.8	19+	11	F	(J)	(J)	399	2373
22.	1988	2-10	2+	W14	20/1	-	#	0	>70	>3000	9+	5.2	9.0/19/1.5	3.2	28-	24	D	(J)	(J)	103	690
23.		3-23	3+	W78	196/3	-	#	0	>1340	1890	6+	11.1	5.0/54/2.5	3.2	27+	21	E	(J)	(J)	192	1374
24.		3-25	2	W50	27/2	-	-	(106)	458	-	6+	12	9.5/-/1	10.0	33+	33	E	(J)	(J)	268	1539
25.		6-06	3(2)	W78	50/2	-	#	x	x	650	8-	-	1.0/30/1	-	20+	18	UL	(J)	(J)	17	135
26.		7-07	3+	W08	125/3	#	#	1700	(3770)	4000	9+	7.8	0.5/31/1.5	23.7	23+	17	E	(J)	(J)	136	686
27.		7-29	3	W44	120/3+	#	#	(2000)	>2100	(30000)	5+	2.0	1.0/59/2	1.5	11-	9	F	(J)	(J)	97	568
28.		8-16	3+	W50	168/3+	-	#	(5800)	5030	18000	7+	5.8	1.5/24.5/-0.5	5.0	20+	12	O	(J)	(J)	208	935
29.		8-21	3(2+)	W17	33/2+	#	(P)	(1450)	1260	155	6-	4.0	13.5/12.5/4.5	3.0	13+	6	E	(J)	(J)	203	1463
30.		8-22	3	W10	170/3+	-	#	0	(1500)	1400	8-	9.1	1.0/34/1.0	10.6	31+	34	E	(J)	(J)	112	1192
31.		8-26	3	W54	240/3+	#	#	(5050)	(5000)	85000	7-	3.8	1.0/26/2.0	16.6	23-	14	E	(R)	(R)	116	776
32.		9-22	2+(2)	W42	35/2	0	0	(49)	336	x	7+	-	6.5/62/0	5.0	7-	4	E	(R)	(R)	209	1087
33.	1989	2-13	3+(3)	W48	40/2	-	#	(440)	x	470	6-	4.0	9.0/28/-2.0	2.6	27+	21	E	(J)	(J)	-	-
34.		5-10	3+	W47	560/3+	#	#	0	(2500)	1050	8+	14.8	2.0/24.5/1	22.0	23+	14	E	(R)	(R)	-	-
35.		7-10	3+	W60	190/3+	#	(#)	(6300)	>1300	>1400	7-	9.9	2.0/36.5/1.0	20.0	20+	13	E	(R)	(R)	-	-
36.		7-14	3+	W04	180/3+	#	#	(6000)	1300	10000	9+	14.5	1.5/17/0	23.7	24-	16	E	(J)	(J)	-	-
37.*		7-16	3+	W30	177/3+	-	#	(1500)	6500	1100	9-	13.5	1.0/18.5/3	21.2	36+	47	E	(J)	(J)	-	-
38.		8-18	3+(3)	W33	120/3	#	#	0	985	6250	6-	6.8	1.0/41/0	3.0	31+	28	E	(J)	(J)	-	1119
39.	1990	3-29	3(2+)	W30	121/3+	-	(#)	8250	0	38000	9-	10.0	1.5/50/2.0	2.6	23+	18	E	(J)	(J)	-	-
40.		3-30	3+(2)	W13	160/3	#	#	0	1750	6000	9-	4.0	5.0/31/45	5.0	26+	20	E	(J)	(J)	-	1650
41.		4-01	3	W11	57/3	-	(#)	0	>1000	4500	7+	5.5	1.5/37/1.0	3.6	65+	241	F	(R)	(R)	-	-
42.		4-05	3(2)	W62	157/3+	#	#	x	2400	300	5+	-	2.0/59/-	3.1	31+	34	F	(J)	(J)	-	-
43.		4-28	3	W34	100/3+	#	#	260	512	x	9+	6.5	1.0/52/13	3.5	47+	84	D	(J)	(J)	-	-
44.		4-29	3(2+)	W21	110/2+	#	#	115	x	x	7+	-	3.0/21.5/13	14.0	41+	55	E	(J)	(J)	-	-
45.*		5-04	3	W90	35/3	-	(#)	0	2650	x	7+	-	0.5/54.5/-	3.4	10+	5	UL	-	-	-	-
46.		5-06	3+	W07	151/3	#	#	0	695	x	8+	11.3	2.0/36.5/0.5	16.0	39+	60	O	(R)	(R)	-	-
47.		5-13	3+(3)	W67	221/3+	#	#	3750	2065	x	6+	3.07	1.0/69.5/1	4.5	20+	11	F	(J)	(J)	-	-
48.*		9-03	3(2+)	W88	126/3+	#	#	12000	5600	>1000	8+	5.0	4.5/21.5/-31	2.7	31-	35	E	(J)	(J)	-	-
49.*		11-12	3+	W04	154/3+	-	#	0	5500	>2000	8+	12.0	1.0/71/0.5	21.2	33+	67	F	(R)	(R)	-	-
50.*		11-15	3+(3)	W35	253/3+	#	#	11600	x	>2700	8+	12.0	2.5/8.5/0.5	20.0	42+	69	(J)	(J)	(J)	-	-
51.*		11-21	3(2)	>W90	82/3-	#	#	0	400	220	6+	2.0	6.0/4.5/-1.5	3.0	36+	45	(J)	(J)	(J)	-	-
52.	1991	7-11	3	W31	245/3+	#	#	0	1500	>900	8+	12.0	6.0/37/1.0	1.3	17-	9	E	(J)	(J)	-	1400
53.		7-12	3+(3)	W22	97/3	(#)**	0	0	4100	22000	8+	12.0	9.0/6/1.0	17.0	9+	5	E	(R)	(R)	-	-
54.*		7-18	3+	W59	113/3	-	(#)**	0	2400	1000	6-	4.0	2.0/39.5/13	10.0	49+	93	E	(R)	(R)	-	-
55.		7-20	3+(3)	W90	370/3+	#	#	0	1800	4000	6-	4.0	5.0/812	Weak	24+	19	(J)	(J)	(J)	-	-
56.		9-10	1	W90	101/3	#	#	0	880	x	6+	3.0	4.0/68/-4	2.9	14+	7	(J)	(J)	(J)	-	-
57.		9-28	3	W29	62/2	#	#	1690	800	>900	9-	7.0	1.0/46.5/0.5	3.3	8+	5	C	(J)	(J)	-	-
58.	1993	9-20	2	W09	214/3	#	#	1400	x	>10000	9-	3.2	1.0/14/10	3.1	22+	13	E	(J)	(J)	-	-
59.		9-26	3	W78	102/3+	0	(#)**	1850	1008	260	6+	2.0	1.0/36/10	4.6	31-	27	(J)	(J)	(J)	-	-

\* Detected at ground level. \*\* Probable Type IV

TABLE 4  
SUNSPOT DATA  
FOR THE 5 DAYS BEFORE THE PCA FLARE

PCA Date	Flare	Sunspot Group		Zurich Class Magnetic Class Field Strength						Sunspot Area Data, Whole Spot						Sunspot Position		
				0	-1	-2	-3	-4	-5	0	-1	-2	-3	-4	-5	L	B	Obs
*1. 1956 2-23	3400	11462	17351	—	E	E	E	F	F	114	155	139	203	175	264	183.0	W21.6	2/17.29
2. 3-10	3431	11514	17389	—	—	—	—	—	—	794	1072	1113	1393	1058	1438	186.8	W17.1	3/15.33
Zurich shows Spot 9-17, Greenwich 14-17 Mt. Wilson 13-18, Tokyo 15-17																		
*3. 8-31	3643	11777	17597	E	E	E	E	E	(b)	97	81	100	97	73	22	94.4	W18.3	9/01.71
				(F)	22	20	15	—	(x)	637	908	918	872	673	171			
4. 11-13	3753	11958	17723	G	E	E	E	E	E	46	60	105	123	131	143	222.7	W16.6	11/12.85
				(F)	16	—	—	—	—	338	627	607	768	814	785			
1957																		
5. 1-20	3820	12085	17829	H	H	H	H	H	H	123	77	91	94	101	81	61.0	W27	1/18.77
				—	(F)	15	17	26	—	557	522	490	636	511	410			
6. 4-03	3907	12235	17935	E	F	D	A	B	A	110	112	101	2	—	1	219.0	W15	3/29.79
				(F)	15	(F)	—	2	2	682	708	470	17	—	6			
7. 6-19				J	J	J	J	(i)		171	175	171	167	24	EL			
				(F)	27	25	—	14	—	931	1004	948	1062	244				
8. 6-22	4024	12415	18071	J	J	J	J	J	J	167	153	156	171	175	171	186.0	W16	6/21.96
				(F)	20	20	20	27	25	816	769	936	931	1004	948			
9. 7-03	4039	12434	18084	H	H	G	G	G	G	108	121	102	89	97	83	76.0	W11	6/30.23
				(x)	—	—	34	—	32	500	600	595	606	546	442			
10. 7-24	4070	12496	18122	E	E	G	G	G	G	81	111	90	80	60	85	139.0	W23	6/22.71
				(F)	19	23	29	26	26	504	568	443	397	388	386			
11. 8-09	4099	12543	18159	J	East Limb					15	Mean Area (14	71	W75 - W60)			190.0	W10	8/14.89
				(F)	18	—	—	—	—	121	—	—	—	—	—			
12. 8-28				E	E	D	—	—	—	95	127	93	85	EL				
				(F)	18	(x)	—	—	—	774	654	585	629	—	—			
13. 8-29	4125	12579	18181	E	E	E	D	—	—	171	95	127	93	85	EL	335.0	W29	8/31.33
				(F)	18	(F)	(x)	—	—	807	774	654	585	629	—			
14. 8-31	4124	12580	18182	E	E	E	E	E	E	227	294	383	264	244	95	329.0	W25	8/31.83
				(F)	24	24	22	—	16	1317	1726	1726	1450	1942	585			
16. 9-02	4125			G	G	G	E	E	E	101	103	113	113	171	95	335.0	W29	8/31.33
				(F)	24	25	22	21	18	626	681	682	629	807	774			
17. 9-12	4134	12596	18194	E	E	E	E	E	E	132	112	121	159	183	181	194.0	W11	9/11.01
				(F)	22	25	26	20	—	701	664	872	967	1102	1327			
18. 9-18	4151	12622	18209	F	E	E	E	C	B	376	244	228	203	86	16	85.0	W23	9/19.30
				(F)	35	26	24	15	10	1998	1482	1327	1034	476	75			
19. 9-21	4152	12634	18216	E	E	A(b)	—	—	—	136	12	Mean Area (91	519	W14 - W85)		60.0	W10	9/21.21
				(F)	26	11	—	—	—	491	49	—	—	—	—			
20. 9-26	4159	12636	18223	C	J	J	C	J	J	49	48	43	47	50	39	338.0	W20	9/27.42
				(F)	25	24	27	25	23	232	249	251	264	246	220			
21. 10-20	4189	12689	18262	F	F	F	F	F	F	399	330	397	332	454	431	70.0	W24	10/17.70
				(F)	27	27	24	29	—	2373	2074	2239	2304	2480	2344			
1958																		
22. 2-10	4400	12997	18496	D	E	E	E	E	E	93	103	81	119	92	128	44.0	W13	2/05.99
				(x)	(F)	—	17	—	—	633	690	633	630	672	789			
23. 3-23				E	E	—	—	—	—	192	175	Mean Area (184	1269	W21 - W83)				
				(F)	20	—	—	—	—	1374	879	—	—	—	—			
24. 3-25	4476	13103	18584	E	E	E	—	—	—	268	220	192	175	EL		92.0	W13	3/28.96
				(F)	20	—	—	—	—	1539	1311	1374	879	—	—			
25. 6-06	4578	13275	18715	E	E	E	E	E	E	16	62	89	102	114	96	341.0	W28	5/30.85
				(F)	18	20	15	—	—	134	436	764	686	728	583			
26. 7-07	4634	13356	18773	E	E	D	A	A(b)	(b)	136	96	56	36	5	3	201.0	W27	6/07.62
				(F)	18	20	—	—	(x)	686	689	510	196	19	15			
27. 7-29	4659	13388	18796	F	F	E	E	E	D	97	108	79	67	50	44	315.0	W15	7/26.25
				(F)	16	16	16	15	—	568	489	375	290	235	237			
28. 8-16	4686	13434	18835	G	G	G	G	G	G	208	175	197	138	154	144	88.0	W13	8/12.38
				(F)	31	34	32	34	—	935	1022	1150	836	880	899			
29. 8-21				E	E	E	E	E	D	203	189	149	169	110	136			
				(F)	24	23	18	17	13	1463	1381	1236	1134	910	945			
30. 8-22	4708	13464	18857	E	E	E	E	E	E	112	203	189	149	169	110	322.0	W18	8/21.89
				(F)	24	23	18	17	—	1192	1463	1381	1236	1134	910			
31. 8-26				E	E	E	E	E	E	116	130	87	123	112	203			
				(F)	16	21	20	24	—	776	751	1010	1128	1192	1463			

TABLE 4  
SUNSPOT DATA (continued)

PCA Date Range			Sunspot Group		Eurich Class Magnetic Class Field Strength						Sunspot Area Umbra, Whole Spot						Sunspot Position		
PCA Date Range			Nr. W. Gr.		0	-1	-2	-3	-4	-5	0	-1	-2	-3	-4	-5	L	B	Obs.
32.	9-22	4765	13544	18912	E 30	E 32	E 30	E 33	E 33	H 30	209 1087	210 1200	200 1137	211 1268	262 1705	270 1775	303.0	S18	9/19.59
33.	2-13	9009	13929	19183	E 30	E 32	H 30	H 33	L 33		Max. Area 1064, 2/15 Mean Area 142, 866						137.0	N08	2/15.82
34.	5-10	5148	14121	19335 19336	E 30	E 32	L 30				Max. Area 806, 5/09 1552, 5/11 Mean Area 76, 563; 136, 947						60 53	N15 N19	5/14.52 5/15.07
35.	7-10				(Y)	(Y)	(Y)												
36.	7-14	5265	14284	19448	H 30	H 32	H 30	H 33	H 33	H 30	Max. Area 1981, 7/17 Mean Area 274, 1412						330	N16	7/14.66
*37.	7-16				(H)	(H)	(H)	(H)	(H)	(H)									
38.	8-16	5323	14356	19498	E 30	E 32	E 30	E 33	E 33	E 30	Max. Area 1119, 8/18 Mean Area 123, 745						266	N13	8/16.16
39.	3-29				(E)	(E)	(E)	(E)	(E)	(E)									
40.	3-30				(E)	(E)	(E)	(E)	(E)	(E)									
41.	4-01	5615	14778		(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 1650, 3/30						30	N12	3/31.5
42.	4-05				(E)	(E)	(E)	(E)	(E)	(E)									
43.	4-28	5645	14815		(E)	(E)	(E)	(E)	(E)	(E)	Area Not Available						96	S06	4/30.4
44.	4-29				(E)	(E)	(E)	(E)	(E)	(E)									
*45.	5-04	5642	14814		(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 850, 4/22						133	N10	4/27.5
46.	5-06	5653	14823		(E)	(E)	(E)	(E)	(E)	(E)	Not Available						7	S08	5/06.9
47.	5-13	5654	14825		(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 1800, 5/12						353	N28	5/08.2
*48.	9-03	5838	15015		(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 800, 9/04						152	N19	9/09.3
*49.	11-12				(E)	(E)	(E)	(E)	(E)	(E)									
*50.	11-15	5925	15114		(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 1775, 11/14						28	N27	11/12.2
*51.	11-21				30° Beyond W.L.														
52.	7-11				(E)	(E)	(E)	(E)	(E)	(E)									
53.	7-12				(E)	(E)	(E)	(E)	(E)	(E)									
*54.	7-18	6171	15353		(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 1400, 7/11						48	S06	7/14.2
55.	7-20				(E)	(E)	(E)	(E)	(E)	(E)									
56.	9-10	6212	15411		(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 1350, 8/31						76	N14	9/04.4
57.	9-28	6235	15435		(E)	(E)	(E)	(E)	(E)	(E)	Area Not Available						87	N11	9/30.7
58.	9-20				(E)	(E)	(E)	(E)	(E)	(E)	Max. Area 1400, 9/15 Daily Areas not Available								
59.	9-26	6964	15768		(E)	(E)	(E)	(E)	(E)	(E)							309	N13	9/20.6

\* Ground level effects

TABLE 5  
PCA FLARE - FLARE DATA

PCA		FLARE					FLARE ACTIVITY					LIFE HISTORY		
No.	Day	No.	OMP	Position L	Av. Max. Area	Brightness E/C/H	Flare			Flares		First Flare	Age Rotat.	Flare Numbers Previous Rotations
							Day	Imp.	OID	Before	After			
1976														
1.	2-23	3400	2/17	187	E20	16000	3/4/3.5	23	3	W80	28/3	0/0	E90/3	2 3379
2.	3-10	3431	3/16	178	E22	3500		10	2	E88	0/0	21/1	E88/2	2 Part of 3400
3.	8-31	3643	9/02	91	E16	10000	3.5/3.5/2.5	31	3	E15	21/0	6/0	E90/2-	3 3598 - 3565
4.	11-13	3753	11/13	221	E16	4000	3.5/3.5/3	13	2	W10	20/0	0/0	E90/2	2 3709
1977														
5.	1-20	3820	1/19	58	E28	9000	3/3/2	20	3	W18	16/1	14/2	E70/3	3, 6 { 3794 - 3767 3797 - { 3770 - 3729 - { 3686 - { 3641 3772 } 3689 } 3642
6.	4-03	3907	3/30.5	209	E13	5200	3/3.5/x	03	3	W60	12/0	12/0	E40/1	6 3872 - 3838 - 3813 - 3788 - { 3755 3757
7.	6-19	4024	6/22.5	179	E18	9000	3.5/3.5/3.5	19	2	E45	5/0	27/2	E57/1	2 { 3989 3991 (In position of 3958)
8.	6-22							22	2	E12	8/1	23/2		
9.	7-03	4039	6/30.0	79	E12	6000	4/4/3	7/03	3+	W40	42/3	0/0	E75/1	2 4001
10.	7-24	4070	7/22.0	148	E21	7000	2/3/2	24	3	W27	28/1	10/1	E58/1	3 4030 - 3993 (In position 3962)
11.	8-09	4099						09	2	E76	1/0	8/0	E90/1	2 { 4066 4072
12.	8-28	4125	8/30.0	353	E27	8000	3.5/3.5/3.5	28	3	E35	17/0	32/5	E87/1	3 4082 - 4044
13.	8-29							28	2+	E30	18/1	31/4		
14.	8-29							29	2	E20	21/2	28/3		
16.	9-02							02	2+	W36	40/5	9/0		
15.	8-31	4124	8/31.5	333	E22	21000	3.5/4/3.5	31	3	W02	42/0	68/0	E90/1	3 { 4083 - 4057 4084 - 4048 4095 4096
17.	9-12	4134	9/10.0	207	E12	9000	3.5/3.5/3.5	11	3	W02	20/2	15/2	E87/1	2, 6 { 4098 - Part of 4065 { 4023-3987-3966 4100 { 3989 4024-3991 4028-4000 4029-Part of 3991
18.	9-18	4151	9/19	89	E19	7800	3.5/4/3	18	3+	E08	30/3	39/2	E90	3, 5 4112 - { 4075 - 4039 - 4001 4078
19.	9-21	4152	9/20.5	69	E11	6000	3.5/4/3.5	21	3	W06	35/0	21/0	E73/2	2 4114
20.	9-26	4159	9/28.0		E20	19000	3.5/3/3.5	26	3	E15	16/0	45/1	E90/1	3, 4 4124 - { 4083 - 4057 4084 - 4048 4095 4096
21.	10-20	4189	10/17.5	73	E25	18000	3.5/3.5/3.5	20	3+	W45	58/3	23/2	E90/1	2 4155 (In position 4120)
1978														
22.	2-10	4400	2/08.3	24	E12	25000	3.5/3.5/4	09	2+	W14	36/0	4/0	E70/1+	2, 3, 4 { 4355 4356 4360 - 4313 4362 - 4310 - 4245
23.	3-23	4476	3/28.5	98	E12	15000	3.5/3.5/3.5	23	3+	E78	5/0	81/4	E90/1	2 4442
24.	3-25							25	2	E50	15/1	71/4		
25.	6-06	4578	5/30	352	E24	8000	2.5/3/3.5	06	2	W78	42/2	1/0	E90/1	4, 6 4529 { 4484 - 4444 4485 - 4446 - 4405 - 4359
26.	7-07	4634	7/07.5	203	E28	9000	2.5/3/3	07	3+	W08	6/0	16/0	E90/1	2 4596
27.	7-29	4659	7/26.5	311	E19	20000	3/3.5/3	29	3	W44	82/0	30/0	E89/1	3 4622-4581
28.	8-16	4686	8/12.5	86	E13	11000	3/3.5/3.5	16	3+	W50	59/1	12/0	E90/1	2 4653
29.	8-21	4708	8/22	321	E18	8000	4/3.5/3.5	21	2+	E17	14/0	42/3	E87/1	3 4657 - 4623
30.	8-22							22	3	W10	29/1	27/2		
31.	8-26							26	3	W54	47/3	9/0		
32.	9-22	4765	9/19.5	305	E18	17000	3.5/3.5/3.5	22	2	W42	52/1	3/0	E67/1	2, 5 { 4712 Part of 4710 - 4659 - 4622 - 4581

TABLE 5 (continued)

Page 2

## PCA FLARE - FLARE DATA

PCA		FLARE						FLARE ACTIVITY					LIFE HISTORY		
No.	Day	No.	OMP	Position L	Av. Max. Area	Brightness E/C/M	Flare Day	Imp.	OID	Flares Before After	First Flare	Age Rotat.	Flare Numbers	Previous Rotations	
1959															
33.	2-13	5009	2/16	134	H12	4000	3/3/3	12	3	H48	30/1 14/0	E90/2	1, 4	{ Mostly new Part of 4969 - 4932 - {4901 4902 4892	
34.	5-10	5148	5/15	53	H14	14000	3.5/3.5/3	10	3+	H47	34/2 56/3	E80/1	2, 10	{ 5100 5095 - 5058 - 5018 - 4976 - 4936 4744 - 4805 - 4854	
35.	7-10	5265	7/14	339	H16	12000	3/3.5/3.5	10	3+	H60	14/0 76/4	E90/1	2, 5	{ 5218 5204 - 5175 - 5105 - 5070	
36.	7-14							14	3+	H04	34/3 56/2				
37.	7-16							16	3+	H30	61/5 29/0				
38.	8-18	5323	8/16	263	H14	6000	3/3/3	18	3	H33	34/0 13/0	E90/1	5	5280 - 5219 - {5165 - 5120 5166	
1960															
39.	3-29	5615	3/31.5	130	H11	3000	3.5/3.5/3	29	2+	H30	5/0 63/1	H45/1	2	5594	
40.	3-30							30	2	H13	16/1 52/1				
41.	4-01							01	3	H11	28/1 40/0				
42.	4-05							05	2	H62	53/2 15/0				
43.	4-28	5645	4/30.5	94	H08	4500	3/3/2.5	28	3	H34	2/0 2/0	H79/1	2	5618	
44.	4-29	5642	4/27.5	134	H27	4500	2.5/3/2.5	29	2+	H21	10/0 13/1	E90/1	3	5615 - 5594	
45.	5-04							04	3	H90	23/1 0/0				
46.	5-06	5653	5/07	8	H07	4000	3/3/3	06	3+	H07	13/0 1/0	E90/1	2	5625	
47.	5-13	5654	5/07	8	H29	2000	3/3/3.5	13	3	H67	31/0 7/0	H63/1	1	New	
48.	9-03	{ 5838 5837 }	9/10	142	H24	10000	3.5/3/2.5	03	2+	H88	0/0 20/0	H88/2+	3	5794 - 5749 (5838 merged with 5837)	
49.	11-12	5925	11/12	30	H24	9000	3.5/3.5/3.5	12	3+	H04	34/2 57/2	H89/1	3	5894 - 5864	
50.	11-15							15	3	H35	52/4 39/1				
51.	11-21							20	2	H90	91/5 0/0				
1961															
52.	7-11	6171	7/14.5	44	H10	5600	3.5/3.5/3.5	11	3	H31	12/0 59/3	H55/1	3	6144 - 6121	
53.	7-12							12	3	H22	17/1 54/2				
54.	7-18							18	3+	H99	57/2 14/1				
55.	7-20							20	3	H90	71/3 0/0				
56.	9-10	6212	9/04.5	77	H15	6000	3.5/3.5/3.5	10	1	H90	66/0 1/0	H83/1	2	6197	
57.	9-28	6235	10/01	87	H15	3600	3/3/3	28	3	H29	11/0 4/0	E90/1	3	6212 - 6197	
1962															
58.	9-20	6964	9/20.5	310	H14	4800	4/3.5/3.5	20	2	H09	65/2 17/1	E90/1	3	6931 - (Part of 6905)	
59.	9-26							26	3	H78	82/2 1/0				

TABLE 6  
ESTIMATED PCA EVENT PROTON FLUX  
AND ASSOCIATED LOOP PROMINENCES

Serial No. Table 1	PCA			Integrated Flux >30 Mev	Flare				Loop Prominence *		
	Date	db	$\Delta t$		Onset	Max	Imp.	CSD	Begin	End	Type
1.	1976 2-23	13.0	0 <sup>h</sup> 23 <sup>m</sup>	$1.0 \times 10^9$	0334	--	3	W80	--	--	--
2.	3-10	3.5	3 <sup>h</sup> 45 <sup>m</sup>	$1.1 \times 10^8$	0515	--	2	B88			
3.	8-31	4.9	2 <sup>h</sup> 04 <sup>m</sup>	$2.5 \times 10^7$	1226	1246	3	E15			
4.	11-13	5.4	5 <sup>h</sup> 30 <sup>m</sup>	--	1430	1501	2	W10			
<u>1977</u>											
5.	1-20	4.1	4 <sup>h</sup> 00 <sup>m</sup>	$2.0 \times 10^8$	1100	1119	3	W18	1250	1320	A-1
6.	4-03	3.9	5 <sup>h</sup> 05 <sup>m</sup>	--	0825	0835	3	W60			
7.	6-19	Weak	6 <sup>h</sup> 06 <sup>m</sup>	--	1609	1613	2	E45			
8.	6-22	5.0	2 <sup>h</sup> 27 <sup>m</sup>	--	0236	--	2	E12			
9.	7-03	9.2	1 <sup>h</sup> 42 <sup>m</sup> 0 <sup>h</sup> 30 <sup>m</sup>	$2.0 \times 10^7$	0712 0830	0745 0840	3+ 3+	W40 W42	0830	0925	A-1
10.	7-24	2.0	3 <sup>h</sup> 03 <sup>m</sup>	--	1712 1810	1737 1828	3	W27			
11.	8-09	3.1	9 <sup>h</sup> 43 <sup>m</sup> 2 <sup>h</sup> 30 <sup>m</sup>	$1.5 \times 10^6$	0617 1330	0629 1355	2 1	E76 W77	1346 1437	1619** >2357	
12.	8-28	Weak	4 <sup>h</sup> 50 <sup>m</sup>	--	0810	0955	3	E35			
13.	8-29	3.2	3 <sup>h</sup> 50 <sup>m</sup>	$1.2 \times 10^8$	{ 28/2010 2024 }		2+	E30			
14.	8-29	8.2	3 <sup>h</sup> 29 <sup>m</sup>				2	E20			
15.	8-31	4.9	1 <sup>h</sup> 18 <sup>m</sup>	--	1257	1313	3	W02			
16.	9-02	7.2	3 <sup>h</sup> 47 <sup>m</sup>	--	1313	--	2+	W36	1525** High Intensity		ADF
17.	9-12	0.5	23 <sup>h</sup> 24 <sup>m</sup>		11/0236	0300	3	W02			
18.	9-18	Weak	{ 3 <sup>h</sup> 02 <sup>m</sup> 1 <sup>h</sup> 46 <sup>m</sup> }	--	{ 1658 1818 }	{ 1740 1840 }	3+	E08			
19.	9-21	5.1	3 <sup>h</sup> 30 <sup>m</sup>	$1.5 \times 10^6$	1330	1335	3	W06			
20.	9-26	2.0	1 <sup>h</sup> 53 <sup>m</sup>	--	1907	1952	3	E15	2050**	Imp. 2	
21.	10-20	7.8	4 <sup>h</sup> 23 <sup>m</sup>	$5.0 \times 10^7$	1637	1642	3+	W45			
<u>1978</u>											
22.	2-10	3.2	8 <sup>h</sup> 52 <sup>m</sup>	$1.0 \times 10^7$	9/2108	2142	2+	W14			
23.	3-23	3.2	5 <sup>h</sup> 13 <sup>m</sup>	$2.5 \times 10^8$	0947	1005	3+	E78	1030	2000	E, 1, 2
24.	3-25	10.0	9 <sup>h</sup> 33 <sup>m</sup>	--	0557	--	2	E50			
25.	6-06	Weak	1 <sup>h</sup> 12 <sup>m</sup>	--	0436	0448	2	W78			
26.	7-07	23.7	0 <sup>h</sup> 20 <sup>m</sup>	$2.5 \times 10^8$	0020	0110	3+	W08			
27.	7-29	1.5	1 <sup>h</sup> 01 <sup>m</sup>	--	0259	0304	3	W44			
28.	8-16	>15.0	1 <sup>h</sup> 28 <sup>m</sup>	$4.0 \times 10^7$	0433	0440	3+	W50			
29.	8-21	3.0	13 <sup>h</sup> 18 <sup>m</sup>	--	20/0042	0045	2+	E17			
30.	8-22	10.6	1 <sup>h</sup> 23 <sup>m</sup>	$7.0 \times 10^7$	1417	1450	3	W10	1610**		
31.	8-26	16.6	0 <sup>h</sup> 55 <sup>m</sup>	$1.1 \times 10^8$	0005	0027	3	W54			
32.	9-22	5.0	6 <sup>h</sup> 22 <sup>m</sup>	$6.0 \times 10^6$	0730	0750	2	W42			

TABLE 6 (cont.)

Serial No. Table 1	Date	FCA		Integrated Flux > 30 Mev	Flare				Loop Prominence <sup>a</sup> Time		
		Q <sub>0</sub>	Δt		Onset	Max	Imp.	CSD	Reg.	End	Type
	<u>1959</u>										
33.	2-13	2.6	8 <sup>h</sup> 59 <sup>m</sup>	—	12/2301	2325	3	B48			
34.	5-10	22.0	2 <sup>h</sup> 05 <sup>m</sup>	9.6 x 10 <sup>8</sup>	2055	2140	3+	B47	2120	2232	EA, 2
35.	7-10	20.0	1 <sup>h</sup> 54 <sup>m</sup>	1.0 x 10 <sup>9</sup>	0206	0230	3+	B60	0504	0900	A, 1
36.	7-14	23.7	1 <sup>h</sup> 20 <sup>m</sup>	1.3 x 10 <sup>9</sup>	0325	{ 0349 0527 }	3+	B04	0530	0900	A, 1
37.	7-16	21.2	1 <sup>h</sup> 36 <sup>m</sup>	9.1 x 10 <sup>8</sup>	2114	2128	3+	W30	2152	2310	A, 3
38.	8-18	3.0	0 <sup>h</sup> 46 <sup>m</sup>	1.8 x 10 <sup>6</sup>	1014	1030	3	W33			
	<u>1960</u>										
39.	3-29	2.6	1 <sup>h</sup> 20 <sup>m</sup>	—	0640	0710	2+	E30			
40.	3-30	5.0	5 <sup>h</sup> 05 <sup>m</sup>	—	1455	1540	2	E13	1511	2040	A, 2, 3
41.	4-01	3.6	1 <sup>h</sup> 17 <sup>m</sup>	5.0 x 10 <sup>6</sup>	0243	0259	3	W11	0937		E, 4
42.	4-05	3.1	1 <sup>h</sup> 45 <sup>m</sup>	1.1 x 10 <sup>6</sup>	0215	0245	2	W62	0304	1617	E, 1, 2, 5
43.	4-28	3.5	1 <sup>h</sup> 00 <sup>m</sup>	5.0 x 10 <sup>6</sup>	0130	0137	3	E34			
44.	4-29	14.0	2 <sup>h</sup> 55 <sup>m</sup>	9.0 x 10 <sup>6</sup>	0107	{ 0210 0359 }	2+	W21			
45.	5-04	3.4	0 <sup>h</sup> 30 <sup>m</sup>	6.0 x 10 <sup>6</sup>	1000	1016	3	W90	1035 **	1314	
46.	5-06	16.0	1 <sup>h</sup> 56 <sup>m</sup>	4.0 x 10 <sup>6</sup>	1404	1448	3+	B07	1540	1700	A, 2
47.	5-13	4.5	1 <sup>h</sup> 01 <sup>m</sup>	4.0 x 10 <sup>6</sup>	0519	0532	3	W67	0546	2135	E, 1, 2, 5
48.	9-03	2.7	4 <sup>h</sup> 23 <sup>m</sup>	3.5 x 10 <sup>7</sup>	0037	0108	2+	B88	0215	1200	
49.	11-12	21.2	0 <sup>h</sup> 45 <sup>m</sup>	1.3 x 10 <sup>9</sup>	1315	1330	3+	W04	1405	1940	A, 3
50.	11-15	20.0	2 <sup>h</sup> 23 <sup>m</sup>	7.2 x 10 <sup>8</sup>	0207	0221	3	W35	0223	0300	E, 6
51.	11-21	3.0	{ 0 <sup>h</sup> 05 <sup>m</sup> 4 <sup>h</sup> 46 <sup>m</sup> }	4.5 x 10 <sup>7</sup>	{ 20/1955 20/2114 }	{ 2020 2135 }	{ 1 2 }	{ W90 W90 }	20/2114 **	2257	
	<u>1961</u>										
52.	7-11	1.3	5 <sup>h</sup> 45 <sup>m</sup>	3.0 x 10 <sup>6</sup>	1615	{ 1659 1710 }	3	E31	1746	1816	E, 2
53.	7-12	17.0	9 <sup>h</sup> 10 <sup>m</sup>	4.0 x 10 <sup>7</sup>	0950	1025	3	E22	1207	1316	A, E, 1
54.	7-18	10.0	2 <sup>h</sup> 10 <sup>m</sup>	3.0 x 10 <sup>8</sup>	0920	1005	3+	W59	1028	1200	E, 1
55.	7-20	Weak	{ 6 <sup>h</sup> 07 <sup>m</sup> 5 <sup>h</sup> 27 <sup>m</sup> 3 <sup>h</sup> 32 <sup>m</sup> }	5.0 x 10 <sup>6</sup>	{ 1553 1633 1828 }	{ 1600 1653 1847 }	3	W90	1605 **	2330	
56.	9-12	2.9	4 <sup>h</sup> 05 <sup>m</sup>	—	1555	1610	1	W90			
57.	9-28	3.3	0 <sup>h</sup> 43 <sup>m</sup>	6.0 x 10 <sup>6</sup>	2202	2223	3	E29			
	<u>1963</u>										
58.	9-20	3.1	0 <sup>h</sup> 46 <sup>m</sup>	—	2314	2403	2	W09	2400	2440	E, 2
59.	9-26	4.6	1 <sup>h</sup> 07 <sup>m</sup>	—	0638	0717	3	W78	0742	2017	E, 1, 2

\* From Bruzek, Ap. J. 140 (2) (1964), 746

\*\* Solar Activity Report Series; 1, 6, 19, 20

A, Seen in absorption

E, Seen in emission

TABLE 7														
SMALL PCA'S REPORTED BY TWO OR MORE INDEPENDENT OBSERVERS														
No.	Date	PCA Seq.	Rise Time, hrs.	Duration hrs.	Abs. db.	Flare Onset	Max. Imp.	Position	PCA Range Start Times	Original Sources	Plage	Sunspot	L	
S1	<u>1955</u> 1-16	1600		48	2	s.			16/1600-16/2230	B <sub>2</sub> , B <sub>2</sub> , JC	3065	11218	61	W36
S2	<u>1956</u> 4-27	2000		48		1546	1+	S14 E14	27/2000-27/2200	B <sub>2</sub> , JC	3477	11596	324	S15
S3	<u>1957</u> 2-21	1800		72-96		1605	1930	3+ W20 W30	21/1800-22/1600	B <sub>2</sub> , DLP, JC JP, S	3856	12140	10	W15
S4	4-06	0800	12	66	3.2	05/1433	1	S15 W90		B <sub>1</sub>	3907	12235	219	S15
S5	4-12	1700				11/1722	1738	3(2+) S23 W04	11/1300-12/1700	B <sub>2</sub> , JC, JP	3923	12254 12258	43	S22
S6	7-01	1200				f			01/ 000-01/1200	CJM, H				
S7	7-28	1500		24	Weak	1340	1402	2 S24 W83	28/1500-28/2100	H, JC, PS	4070	12496	139	S23
S8	9-22	1000				0643 0732	1+ 0750	2 S24 W32 2 S23 W38	22/1000-22/1200	H, PS	4151	12622	85	W23
S9	11-05	0030	10	46	2.6	04/0058 1058 1732	0102 1 1740	1 S20 W38 1 S24 W39 1 S25 W45	04/2300-05/0300	B <sub>1</sub> , B <sub>2</sub> , DLP, H JC, PS	4207	12732	240	S24
S10	12-17	1300			Weak	0734	0737	2 W20 W41	17/0300-17/1600	H, JP, PS	4314	12855	313	W18
S11	12-28	2300		30	Weak	2229	2230	2 W25 W50	28/2300-28/2400	H, JC, PS	4321	12874	263	W22
S12	<u>1958</u> 3-11	0400			Weak	0030	0042	1 W11 W02	11/0300-11/1000	B <sub>2</sub> , JC, PS, S	4449	13076	307	W11
S13	3-14	2200				1454	1507	2 S21 W84	14/1500-14/2200	B <sub>2</sub> , CJM, JP, PS, S	4445	13063	15	S18
S14	3-31	1600				31/0005 30/2345 31/0038 31/0025	0014 2340 0052 0031	2 S17 W22 1 S10 W31 2 S08 W23 2 W37 E59	31/WFG -31/1600	JC, JP	4476 4484	{13103 13110 13110 13118}	92	S13
S15	4-10	0900	9	68	4.4	f				B <sub>1</sub> , B <sub>2</sub> , B <sub>2</sub> , CJM JP, K, L <sub>1</sub> , PS, RL, S				
S16	<u>1959</u> 1-26	1500				0842	0900	3 W16 W61		JC, JP	4069	13878	106	W17
S17	6-13	1330			1.5	0357	0358	1 W17 E58	13/0800-13/1330	B <sub>2</sub> , JC, K	5204	14211	330	W17
S18	9-02	0400		48	Very small ~1.5	1923 1648 1947 02/0310	1938 1704 1953 0434	2+ W12 E60 2+ S12 W52 1+ W09 W15 1+ W17 E21		B <sub>2</sub> , RHO, C	5354 5340 5344 5340	14414	355	W12
S19	<u>1960</u> 1-11	2200		96	VS	2040	2126	3 W22 E03	11/2200-12/0700 13/1600-13/2000	B <sub>1</sub> , G JC, S	5527	14660	101	W19
S20	9-26	0900		120	2 db	0525	0537	1+ S22 W64	25/2100-26/2300	G, JC, JP, K	5858	15043	353	S19
S21	<u>1961</u> 11-10	1500			2 db	1434	1444	1+ W19 W90	10/1500-10/1600	B <sub>1</sub> , B <sub>2</sub> , BO	6264	15461	5	W09
S22	<u>1962</u> 2-01	2030			1-2db	0901	0907	2 W10 W36		BO, Sat	6326	15507	298	W10
S23	<u>1963</u> 4-15	1200				1034	1125	2 S11 W06		BO, Ma	6766	15714	246	S12

\* Most probable flare  
f No reasonable flare or region association  
s Sunspot and plage associations reasonable



TABLE 8  
PCA'S REPORTED BY GREGORY ONLY DURING 1960

PCA				Flare				Delay Hours	Source Station	Solar Active Region				Flare Age	
No.	Date	UT Hrs	Duration Days	Beginning	Max	Importance	Position			Flare	Region	No.	L		
02	1-15	03	1	1334		2	S20 W68	14	HLS	5525	1422-45	14657	121	S17	New
03	2-7	07	4	*06/1340 06/1426	1344	1 2	S13 W81 S15 W03	17.5	Scott B.	5551	1423-3	14701	196	S13	4
04	2-15	10	4	as											
05	2-29	16	8	*1522 0140	1546	1 2	N22 E04 S32 W56	<1	Scott B.	5586	1424-21	14738	172	N24	2, 5
06	3-10	18	2.5	1716	1720	1	N25 E08	1	HLS	5592	1424-39	14751	41	N25	3
07	3-17	18	3	1616	1620	1	N05 W32	1	HLS	5597	1425-1		349	N06	5
08															
11	4-15	10	4	*0717 0950	0719 0957	1 1	N12 W17 N23 E68	2.5	HLS	5627	1426-11	14796	313	N11	New
16	5-09	08	> 3	0704	0734	3	S16 E55	1	HLS	5657	1427-11	14831	279	S09	3
18	5-17	15	2	*0418 1414	0425 1418	1+ 1-	S09 E33 N18 W08	11	HLS	5663	1427-28	14840	197	S12	3
19	5-26	10	3	0818	0928	2+	N16 W15	2	HLS	5669	1427-40	14849	126	N13	4
20	6-01	14	6	0824	0900	3+	N28 E39	6	HLS	5680	1428-02	14867	343	N30	2
21	6-15	10	2	0635	0653	2	S09 E08	4	HLS	5695	1428-22	14888	199	S12	4
22	6-25	17	> 2	1131	1215	3	N19 E04	6	HLS						
23	6-27	23	> 1	2140	2156	3	N17 W23	1.5	HLS	5713	1428-39	14908	69	N20	New
24	6-28	19	1.5	*1214 1815	1217 1825	1 1	N21 W37 N08 E68	7	HLS						
25	8-11	24	5	1916	1929	2+	N22 E27	5	HLS	5794	1430-13	14981	143	N20	2
26	8-26	10	5	0847	0852	1	N17 W90	1	HLS	5802	1430-23	14989	68	N17	3
29	10-3	16	10	as					HLS						
30	10-29	12	8	1026	1030	3	N14 E25	1.3	HLS	5909	1433-19	15099	185	N12	New
31	11-10	18	> 1	1009	1023	3	N28 E28	8							
32	11-11	04	> 1	0305	0340	2	N28 E12	1	HLS						
34	11-14	22	> 1	2114	2120	1+	N35 W27	1	All	5925	1433-39	15114	28	N27	3
36	11-19	12	> 2	1001	1059	1	N25 W90	2	Southern						
38	12-06	05	6	5/1825	1839	3+	N26 E68	11	HLS	5959	1434-38	15151	8	N25	4
* Preferred Flare as No Reasonable Flare Association PCA's Reported by Gregory and Others: For: 01, 28 See Table 7: 819, 20 For: 6-8, 9, 10, 12, 13, 14, 15, 17, 27, 33, 35, 37 See Tables 1-5 : 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51															

**TABLE 9**  
**ANALYSIS OF PCA EVENTS DURING 1960 AND EXPLORER VII DATA**

No.	Date	Hr.	Duration	db	Integrated Flux	$\Delta t$ hr	Flux	$\Delta t$ hr	Flux	Duration
8-19, G1	1-11	2200	96h	VS	--	-11.5	0.4	29	2.0	>74.5
* (1) G2	1-15	0300	24h	VS						
(2) { G3	2-07	0700	4d	VS						
{ G4	2-15	1000	4d							
{ G5	2-29	1600	8d							
{ G6	3-10	1800	60h							
G7	3-17	1800	72	VS		- 3.5	0	70.5	0.6	104.0
39, G8	3-29	0800	73	2.6		3.5	0.3	20.0	0.6	43.5
40	3-30	2000	> 36	5.0		11.5	0	26.0	0.7	27.5
(3) 41, G9	4-01	1000	73	3.6	$5 \times 10^6$	- 1.5	-0.5			
						- 0.5	+1.6	1.0	220+30	47.0
42, G10	4-05	0400	55	3.1	$1.1 \times 10^6$	3.0	0.7	5.0	>5.4	
(4) G11	4-15	1000	96	VS						
43, G12	4-28	0230	30	3.5	$5 \times 10^6$	1.0	0.7	16.0	>33.0	39.5
(5) 44, G13	4-29	0400	114	14.0	$7 \times 10^6$	~15.0	10.0	3.5	17.0	<23.0
(6) 45	5-04	1030	8	3.4	$6 \times 10^6$	5.0	3.7	3.5	>41	~10.0
(7) 46	5-06	1600	103	11.0	$4 \times 10^6$	<- 1.5	4.3	<4.0	14	11.0
(8) G16	5-09	0800	72	VS						
47, G17	5-13	0620	65	4.5	$4 \times 10^6$	7.0	2.3	1.5	51	29.5
(9) G18	5-17	1500	48	VS		1.0	0	21.0	1.5	70.0
(10) G19	5-26	1000	72	VS		0	1.3	0	1.3	26.0
(11) G20	6-01	1400	144	VS		<- 3.5	0.6	1.5	5.0	51.0
(12) { G21	6-15	1000	48	VS						
{ G22	6-25	1700	> 48	VS						
{ G23	6-27	2300	> 24	VS						
{ G24	6-28	1900	36	VS						
(13) G25	8-11	2400	120	VS		< 12.5	> 2.0	0	> 2.0	>95.5
(14) G26	8-26	1000	120	VS						
(15) 48, G27	9-03	0500	89	2.7	$3.5 \times 10^7$	<8.5	141+14	2.5	255+29	>143.5
(16) 820, G28	9-26	0900	120	2.0						
(17) { G29	10-3	1600	240							
{ G30	10-29	1200	172							
(18) { G31	11-10	1800	> 1							
{ G32	11-11	0400	> 1							

\* ( ) See Notes, Appendix 2

**TABLE 10A**  
**IMPORTANCE 3+ FLARES FOLLOWED**  
**BY MAJOR FCA EVENTS**

		FLARE DATA	EMERSON		LADDO OBSERVATION		FCA		Integ. Flux/cm <sup>2</sup> > 30 Mv		Table 1 Serial No.					
Serial	Date	Flare CND	Area	Ave. Bright	Total Flares	Age	Magn. Class	Surich Class	L.	Dur. Min./Sec.	Obs'd Dur./Min.	Spectral	At hr.	Obs		
1.	7-03	W40	6000	4.0	43	2	14 <sup>pl</sup>	H	76	44/3	Mag/(736)/25 Mag/585/31 Sec/205/30	IV	1.5	9.2	1.0x10 <sup>7</sup>	9
2.	10-20	W45	18000	3.5	92	2	14 <sup>pl</sup>	F	70	156/3+	Oct/(4000)/51	II, IV	4.5	7.8	5.0x10 <sup>7</sup>	21
3.	3-23	W78	15000	3.5	90	2	14 <sup>pl</sup>	H	92	196/3	Mag/21340/2110 Jod/21190/10	IV	5.0	3.2	2.9x10 <sup>8</sup>	23
4.	7-07	W08	9000	3.0	23	2	44 <sup>pl</sup>	H	201	125/3	Tok/3770/100 Mag/(990)/10 Mag/(1700)/30 Oct/(875)/8.5	II, IV	0.5	23.7	2.9x10 <sup>8</sup>	26
5.	8-16	W50	11000	3.5	72	2	14 <sup>pl</sup>	G	88	168/3+	Tok/5030/70 Mag/(5800)/60	(IV)	1.5	>15.0	4.0x10 <sup>7</sup>	28
6.	5-10	W47	14000	3.5	97	2, 10	14 <sup>pl</sup>	H	60	560/3+	Oct/(2500)/160	II, IV	2.0	22.0	9.6x10 <sup>8</sup>	34
7.	7-10	W63	12000	3.5	96	2, 5	14 <sup>pl</sup>	H	330	190/3+	Mag/6300/38	II, (IV)	2.0	20.0	1.0x10 <sup>9</sup>	35
8.	7-14	W04								180/3+	Mag/6000/100	II, IV	1.5	23.7	1.3x10 <sup>9</sup>	36
9.	7-16	W31								177/3+	Oct/(6500)/180 Mag/(1500)/60	IV	1.0	21.2	9.1x10 <sup>8</sup>	37
10.	5-06	W07	4000	3.0	14	2	24 <sup>pl</sup>	G	7	151/3	Mag/620/28 Oct/695/90	II, IV	2.0	16.0	4.0x10 <sup>6</sup>	46
11.	11-12	W04	9000	3.5	98	3	14 <sup>pl</sup>	F	28	154/3+	Oct/5500/340	IV	1.0	21.2	1.3x10 <sup>9</sup>	49
12.	7-18	W59	5600	3.5	79	3	44 <sup>pl</sup>	H	48	113/3	Mag/2400/65	(IV)	2.0	10.2	3.0x10 <sup>8</sup>	54

**TABLE 10B**  
**IMPORTANCE 3+ FLARES FOLLOWED**  
**BY SMALL FCA EVENTS**

1.	1957	W30	2800	2.5	4	4	44 <sup>pl</sup>		10	--	Oct/19/240	II	2.0 Weak	7/53 **
2.	9-18	W08	7800	3.5	83	5	44 <sup>pl</sup>	F	85	43/3+	Oct/(275)/40	IV	3.0 Weak	1/18
3.	1960	W46	7000	3.0	34	2	14 <sup>pl</sup>		343	75/3	Mag/3400/60	(IV)	6.0 V. small 4x10 <sup>5</sup>	8/020
4.	12-05	W68	6500	3.0	13	4	14 <sup>pl</sup>	C	17	100/3	Oct/330/27	II, IV	11.0 V. small	8/038

\* Flare Reported by Sacramento Peak only  
\*\* Table/Serial No.  
\*\*\* An important FCA would be expected

**TABLE 10C**  
**IMPORTANCE 3+ FLARES NOT FOLLOWED**  
**BY A FCA EVENT**

1.	1956	W32	4000	3.5	21	New	14 <sup>pl</sup>	H	264	21/2		(IV)	No FCA expected	
2.	1957	W17	16000	3.5	37	3	44 <sup>pl</sup>	H	18	None	None reported		No FCA expected.	
3.	W1-31	W05	8500	3.0	3	2	44 <sup>pl</sup>	C	257	84/1	Tok/234/120	II	No FCA expected.	
4.	W11-29	W63	1000	1.5	1	2	No spot			None	None reported	II	No FCA expected.	
5.	1959	W67	6000	3.5	46	5	14 <sup>pl</sup>	D	273	93/3+	Mag/(2300)/8		A FCA might be expected.	
6.	4-05	W12	9000	3.5	69	4	14 <sup>pl</sup>	G	330	22/2+	Oct/(1225)/180	(IV)	A FCA would be expected.	

\* Flare reported by Sydney only

# Ott Ottawa 2800 Mc/s  
Mag Madarborst 2980  
Gor Goriky  
Jod Jodrell  
Tok Rank 3000  
Mag Tokyo  
Mag Nagoya 3750

TABLE 11

FLARES WITH IMPORTANCE 3+ BY AT LEAST ONE OBSERVATORY.

REDUCED TO IMPORTANCE 3 IN THE MONTH-SUMMARY WORKING LISTS

No.	Date	Place Obs	Flare Region	No. rep/ No. 3+	FLARE DATA				EFFECT			AUDIO OBSERVATIONS			PCA			
					Area	Ave Max. Bright	Total Flare	Age	Mg. Class.	Class. L	SW	Obs./Flare/Sec.	Min. Spectral	IV	Δt	Δb	Integrated Flare	Serial No.
1.	1976 8-31	E15	3643	11/1	10000	3.5	30	3	1X1	E	94	81/3	Oct/(340)/39	(IV)	2.0	4.9	2.5x10 <sup>7</sup>	3
2.	1977 1-06	H40	3813	6/1	19000	3.5	27	3	1X1	E	183							
3.	8-28	E33	4125	11/2	8000	3.5	61	3	1X1	E	335	138/3	Nov/1192/40	(IV)		Weak		12
4.	8-31	W02	4124	8/1	21000	3.5	110	2, 3	1X1	E	389	184/3+	Oct/(3900)/65	IV		4.9		15
5.	9-19	B02	4151	5/1	7800	3.5	83	5	0X1	F	85	54/3	Nov/(1080)/11 Tok/1410/10	IV				
6.	11-24	E37	4263	7/1	8900	3.5	38	4	1X1	O	263	32/3-	Nov/6-998/40	IV				
7.	1978 1-25	H69	4372	17/1	3500	2.0	10	4, 6	0X1	E	269	74/3	Nov/358/83 Nov/278/40					
8.	3-01	H46	4436	5/1	1400	3.5	15	Nov	0X1	E	148	12/2+	Nov/458/2 Nov/296/4					
9.	3-03	B60	4445	8/1	10000	3.0	45	3, 4, 5	1X1	F	15	95/3+	Nov/1338/28	(IV)				
10.	1979 2-12	H48	5009	2/1	4080	3.0	43	1, 4	1X1	E	137	40/2	Nov/(440)/70	IV		2.6		33
11.	5-11	H41	5148	4/1	14000	3.5	97	2, 10	1X1	E	96	67/3-	Oct/(900)/200	II, IV	This is the region of very large PCA on May 10			
12.	7-14	E37	5273	14/1	4000	3.0	12	2	1X4	B	296	105/2+	Oct/(85)/30					
13.	7-16**	W27	5265	8/1	18000	3.5	96	2, 5	1X1	E	330	28/2-	Oct/(350)/9	II	This is in the region of the large PCA on the 10, 14, and 16th			
14.	8-18	H33	5323	17/2	6000	3.0	48	4	1X1	E	260	120/3	Nov/621/106 Sim/720/23 Nov/585/23	(IV)		3.0	1.8x10 <sup>6</sup>	38
15.	1980 5-09	B32	5657	7/1	4000	3.0	7	3	1X1	J	279	98/2	None reported					
16.	5-13	H67	5654	6/1	2000	3.0	38	Nov	1X1	F	353	221/3+	Nov/1790/105 Tok/2065/101	II, IV		4.5	4x10 <sup>6</sup>	47
17.	11-10***	E29	5985	9/1	9000	3.5	98	3	1X1	F	28	90/2	Nov/360/12 Nov/6-600/33	II, IV		20.0	7.2x10 <sup>8</sup>	50
18.	11-15	W08		2/1								253/3+	Nov/11600/80					
19.	1981 7-12***	E22	6171	19/4	5600	3.5	78	3	1X1	E	48	97/3	Nov/4100/87 Oct/45/225	(IV)		17.0	4x10 <sup>7</sup>	53
20.	7-15	E15	6172	8/1	5000	3.0	5	2, 3	1X1	O	14	113/3	Oct/54/458 Nov/61/8	IV		Weak		
21.	7-20	H90	6171	3/1	5600	3.5	78	3	1X1	E	48	370/3+	Oct/1800/42 Oct/250/222	II, IV		Weak	9x10 <sup>6</sup>	55

\* Oct Ottom 2800 Hz/s  
Nov Heinrich Hertz 2980  
Sim Simferopol 3000  
Tok Tokyo  
Nov Nagoya 3750

\*\* The PCA and ground level effect on July 16, 1959 is generally associated with the 3+ flare at 2114 UT E26 W31 (No. 9 Table 11A, No. 37 Table 1). These events probably should be considered in the combined effect of the importance 3 flare at 1985 (No. 13, Table 10) and the 3+ flare at 2114.

\*\*\* Flares Numbers 17 and 18 are from same region; Flare 5985.  
Flares 19 and 21 are from the same region; Flare 6171.

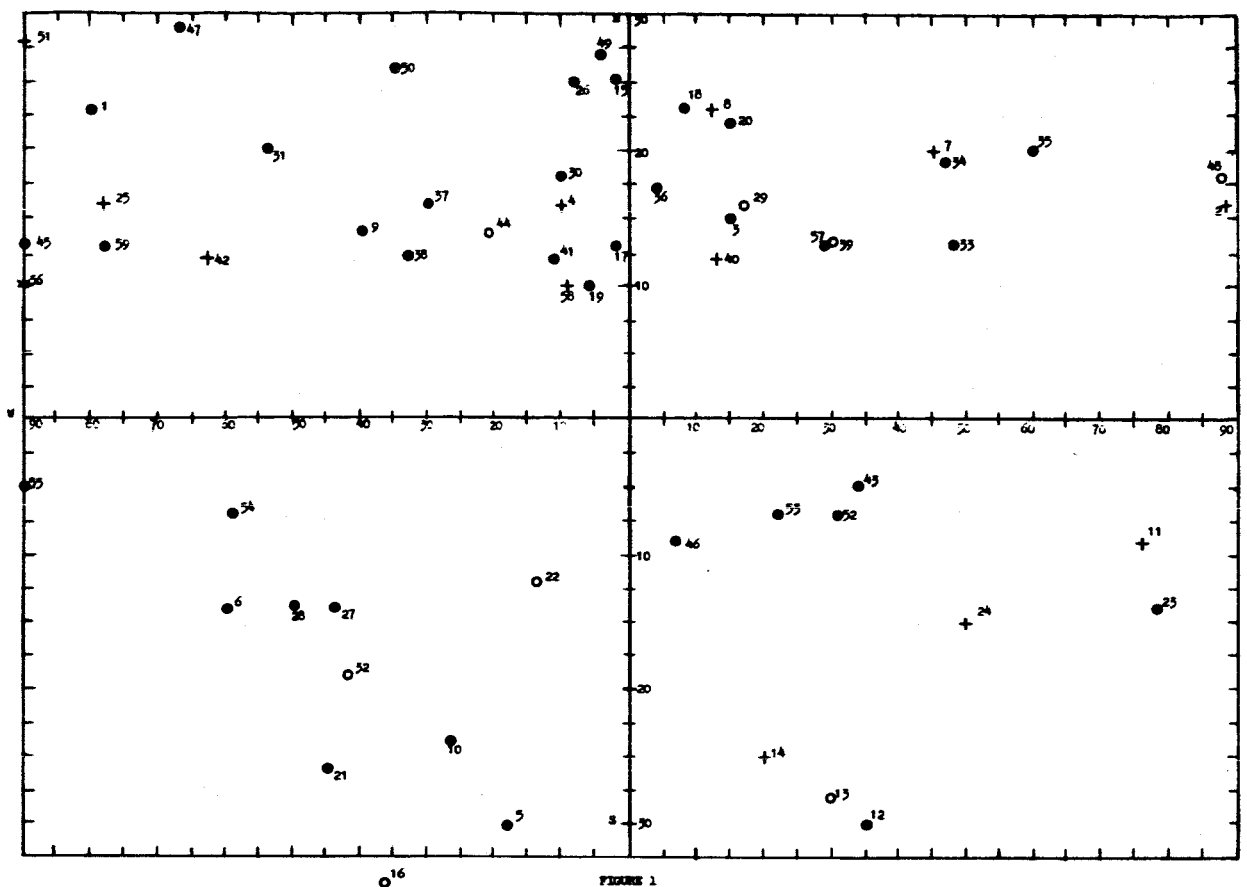


FIGURE 1  
HELIO-GRAPHIC POSITION OF PCA PLANES  
● 3+, ● 3, ○ 2+, + 2, × 1

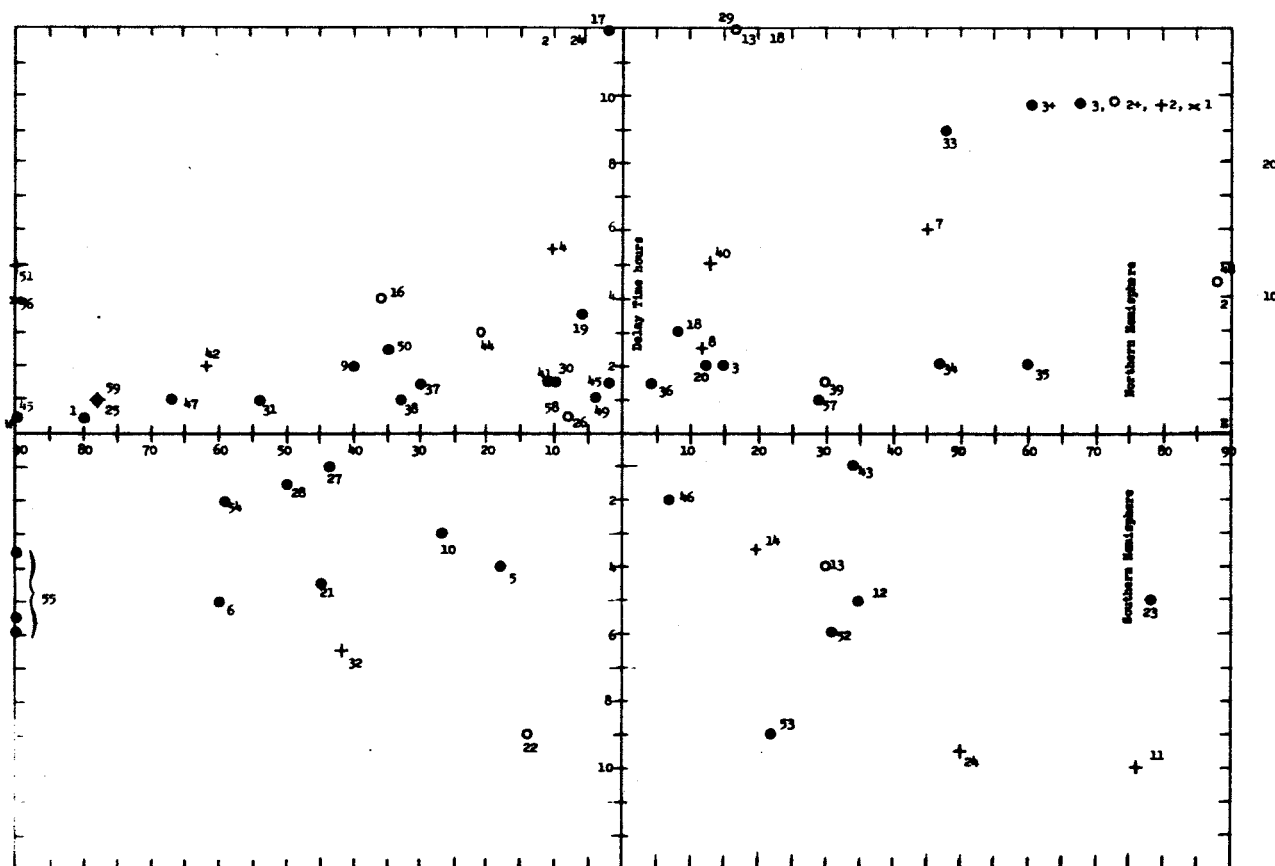


FIGURE 2  
PLANE TO PCA TIME DELAY AS A FUNCTION  
OF THE PLANE CENTRAL MERIDIAN DISTANCE

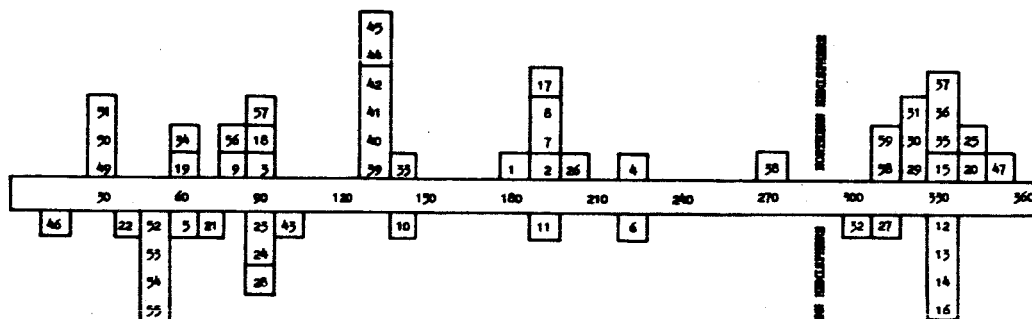


FIGURE 3  
HELIO-GRAPHIC LONGITUDE DISTRIBUTION  
OF PCA PLANE SUMMITS

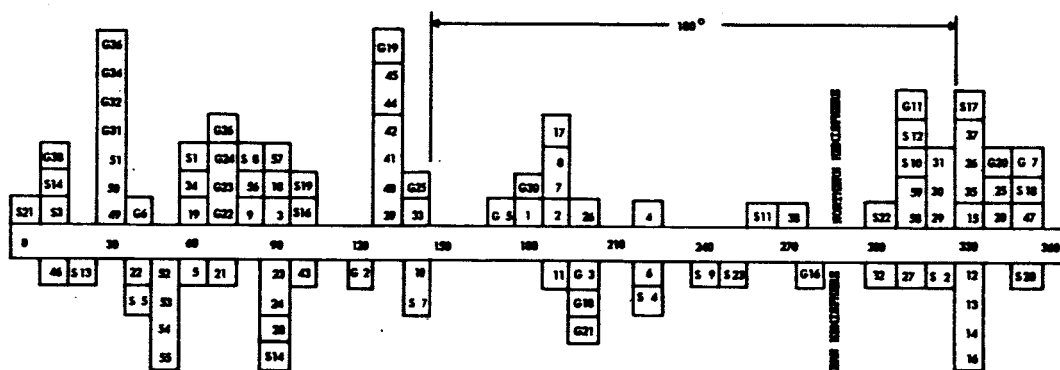
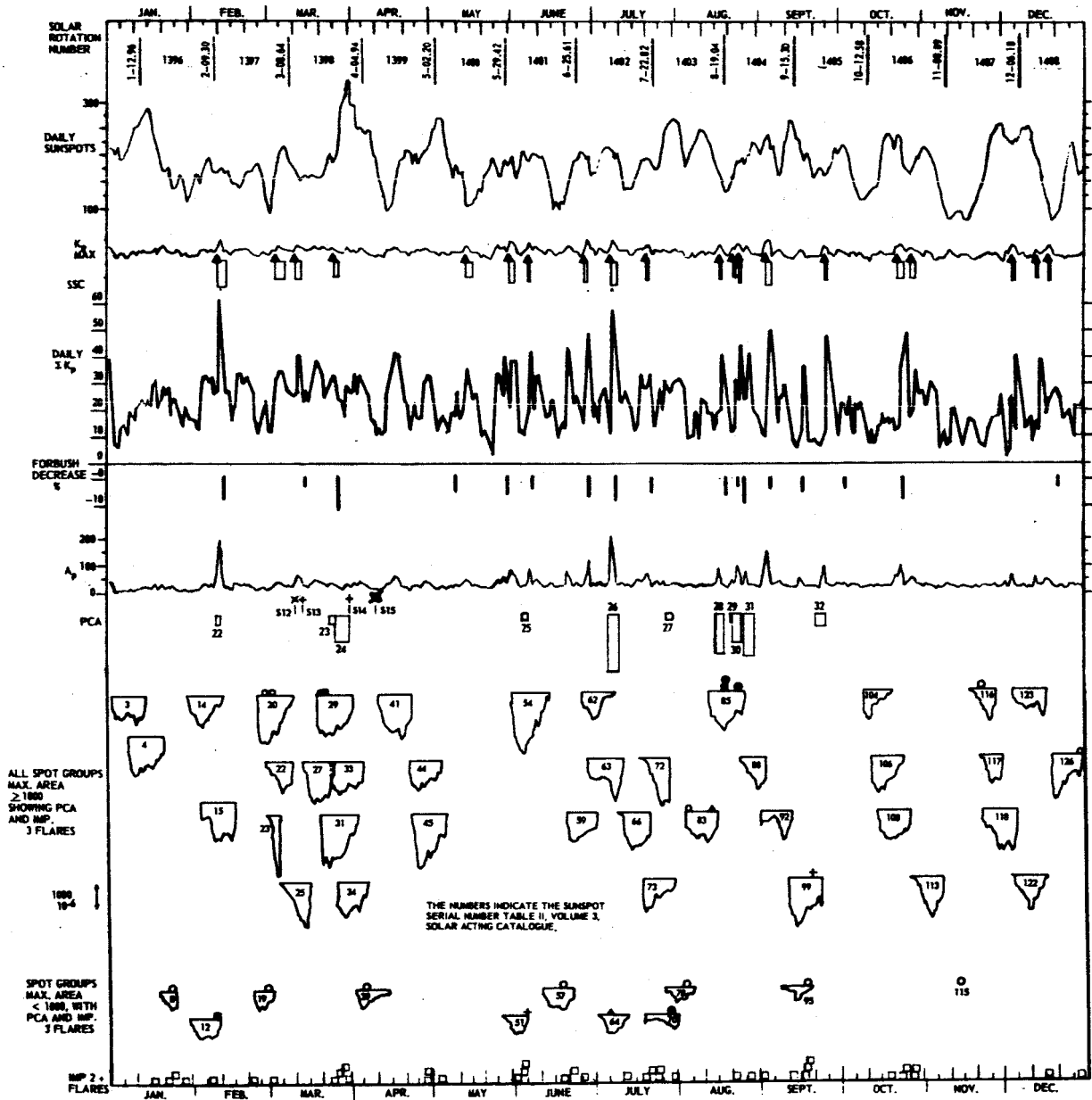


FIGURE 4  
SUMMIT HELIO-GRAPHIC LONGITUDE DISTRIBUTION  
ALL PCA'S REPORTED IN THE LITERATURE  
AND LISTED IN TABLES 1, 7, AND 8

FIGURE 5 SOLAR ACTIVITY DURING 1958



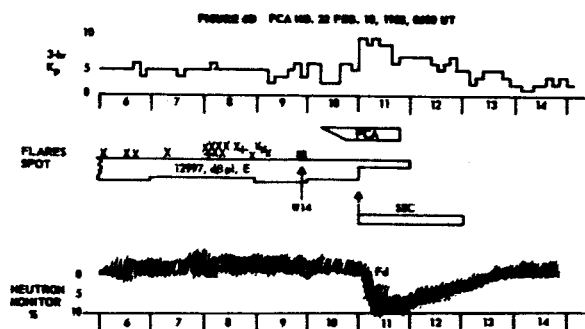
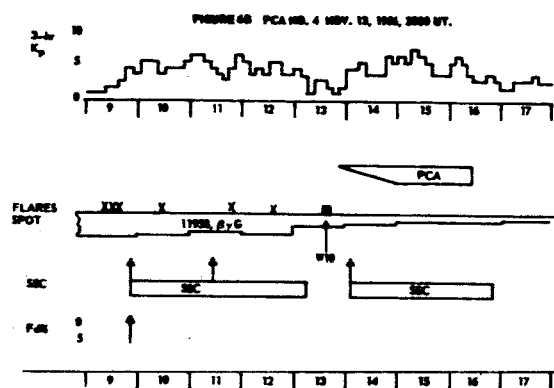
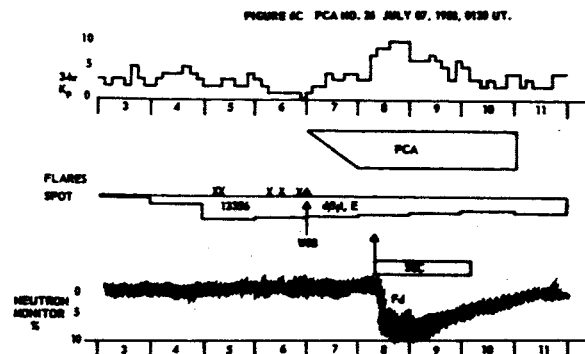
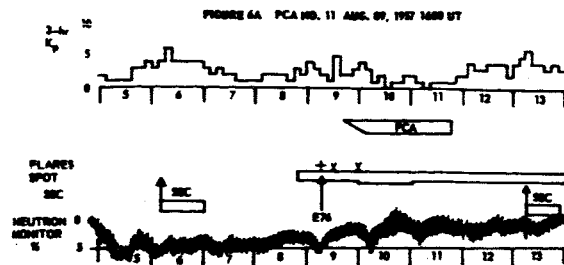


FIGURE 7A PCA'S NO. 35, 36, 37 JULY 10, 14, 16, 1959, 0400, 0445, & 2230 RESPECTIVELY

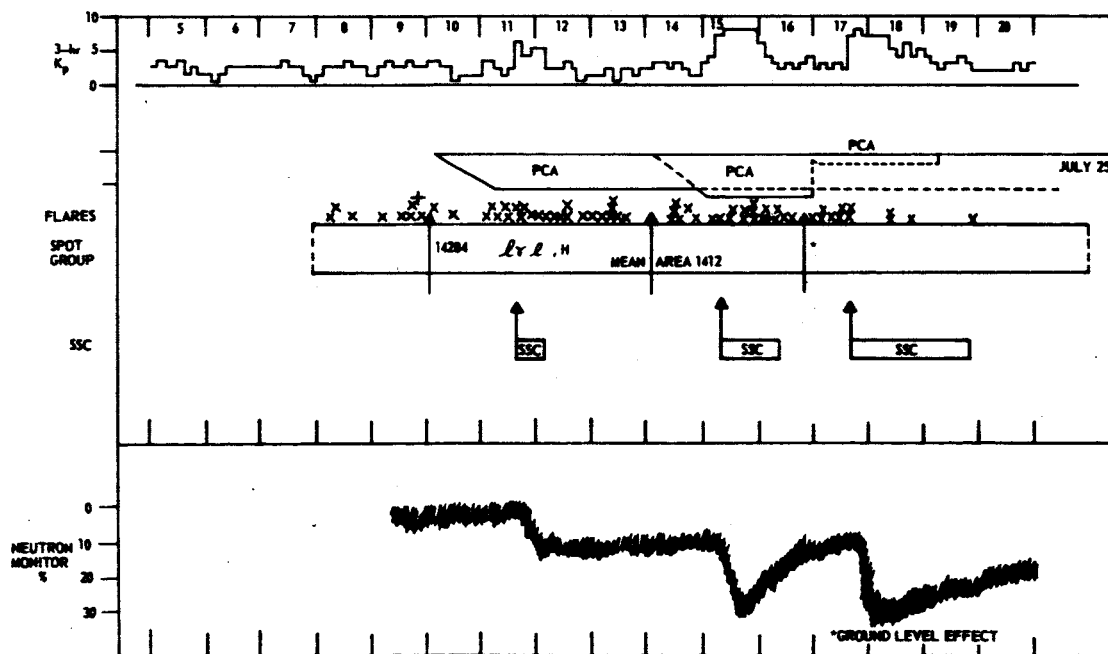




FIGURE 7B. PCA'S NOS. 29, 30, 31 - AUG. 21, 22, 26, 1968

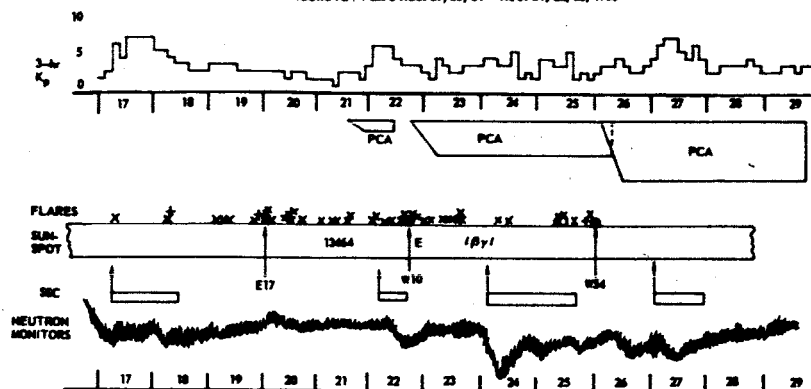


FIGURE 8A. FLARE NOV. 07, 1966, 1100 UT. IMP. 3, NO PCA, WITH LOOP PRESENCE 1313 UT.

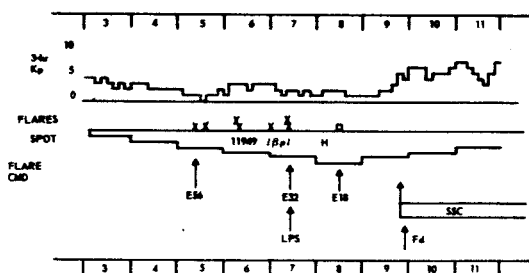


FIGURE 8C. IMPORTANCE 3 FLARE MARCH 3, 1968 WITH LOOP PRESENCE, NO PCA

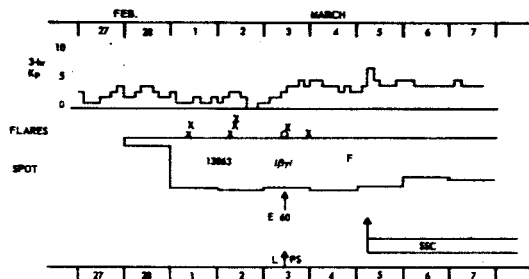


FIGURE 8B. FLARE APRIL 14, 1967, 1040 UT. IMP. 3, NO PCA, WITH LOOP PRESENCE 10M - 24M

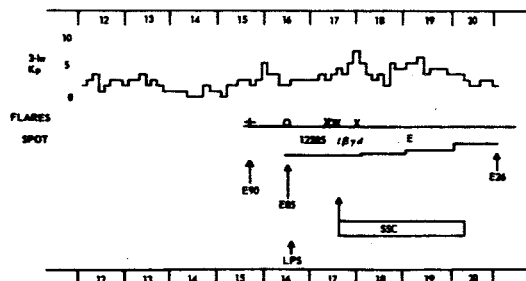
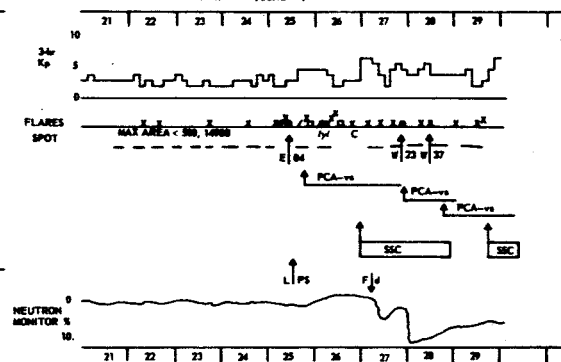


FIGURE 8D. IMPORTANCE 3 FLARES ON JUNE 25, 1968 WITH LOOP PRESENCE AND SMALL PCA, JUNE 27, 1968 SMALL PCA NO LOOP PRESENCE



CODE USED FOR FLARES

IMPORTANCE	WITH PCA	WITHOUT PCA
3	A	A
2	O	O
2	D	D
1	X	X